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I, the undersigned, hereby declare that the annexed document is an accurate English translation of the below-identified document, that the translation was duly made by me, and that I am fully familiar with both English and Japanese, for which I will assume any responsibility:

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This is to certify that the annexed is a true copy of the following application as filed with this Office.

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[Title of the Invention]
AUTOMOTIVE PASSENGER RESTRAINT AND PROTECTION APPARATUS AND SEATBELT PROTRACTION AND RETRACTION AMOUNT-DETECTING DEVICE

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[Name of Document] SPECIFICATION

[Title of the Invention]

AUTOMOTIVE PASSENGER RESTRAINT AND PROTECTION APPARATUS

[What is claimed is]

[Claim 1]

An automotive passenger restraint and protection apparatus having an electric retractor for retracting and protracting a seatbelt, an airbag device for causing expansion of an airbag to restrain an occupant, and a pretensioner for rapidly retracting the seatbelt to restrain the occupant,

characterized by comprising:

speed detecting means for detecting a speed of protraction of the seatbelt through said electric retractor; and

control means for controlling at least one of actuation time of said airbag, expansion pressure of said airbag, actuation time of said pretensioner, a force of said pretensioner for retracting the seatbelt, and a force of said electric retractor for retracting the seatbelt, based upon the speed of protraction of the seatbelt detected by said speed detecting means.

[Claim 2]

An automotive passenger restraint and protection apparatus as claimed in claim 1, further including seatbelt locking means for locking the seatbelt from being protracted when the seatbelt is protracted at a predetermined or higher degree of acceleration, and abnormality diagnosis means for carrying out a diagnosis as to abnormality of said seatbelt locking means by making a determination as to whether said seatbelt locking means has operated, in response to acceleration at which the seatbelt has been protracted.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

This invention relates to an automotive passenger restraint and protection apparatus for automotive vehicles such as automobiles, which uses an electric retractor for retracting and protracting a seatbelt for protection of an occupant (driver or passenger).

[0002]

[Prior Art]

An automotive passenger restraint and protection apparatus is already known, which is provided with an airbag device for restraining an occupant through expansion of an airbag, a belt pretentioner for restraining the occupant by suddenly retracting a seatbelt, an airbag and pretensioner controller for controlling actuation time and expansion pressure of the airbag and actuation time and seatbelt-pulling force of the pretensioner, and a sensor for detecting negative acceleration acted upon the occupant upon a collision of the automotive vehicle.

[0003]

When negative acceleration acted upon the occupant is detected by the sensor upon a collision of the automotive vehicle, a signal indicative of the negative acceleration from the sensor is delivered to the airbag and pretensioner controller, which in turn controls the actuation time and expansion pressure of the airbag and actuation time and seatbelt-winding force of the pretensioner, whereby the airbag and the pretensioner are actuated.

[0004]

Then, fault diagnosis of the seatbelt locking mechanism has conventionally been carried out through a determination by the occupant or the like as to whether the seatbelt can be actually retracted and protracted, or as to whether the seatbelt can be locked in position by suddenly protracting the same.

[0005]

[Problems to Be Solved by the Invention]

The problems to be solved by the present invention include problems classified into two large groups. In the first problem, in the known automotive passenger restraint and protection apparatus, the actuation time and expansion pressure of the airbag are controlled by the airbag and pretensioner controller upon a collision of the automotive vehicle, irrespective of the protracting speed of the seatbelt. Consequently, for example, when it is judged by the controller that the actuation times for actuating the airbag and the pretensioner should be set to longer values, the airbag and the pretensioner are actuated with the longer actuation times even in the event that the protracting speed of the seatbelt is so high that the occupant can collide against equipment within the compartment.

[0006]

Further, when it is judged by the controller that the expansion pressure for actuating the airbag should be set to a higher value, the expansion pressure of the airbag cannot be changed according to the protracting speed of the airbag even in the event that the protracting speed of the seatbelt is so high and the occupant is restrained by the airbag expanded under such a higher expansion pressure that the occupant can directly receive a large impact applied to the vehicle.

[0007]

Also, conventionally there is known a mechanism called "EA mechanism" (load limiter) which has a function of causing the reel shaft to rotate in the direction of protracting the seatbelt when a tension in excess of a prescribed value is applied to the seatbelt immediately after a collision of the automotive vehicle, so as to control the tension to or below the prescribed value (hereinafter referred to as "the EA function"). The EA function is terminated when the seatbelt is protracted by a certain length after the EA function is made effective. That is, the EA function is carried out irrespective of the degree of magnitude of collision of the automotive

vehicle. Consequently, in the event of a strong collision of the automotive vehicle, for example, the EA function can be terminated even at a time point when it is desired that the same function should be still exhibited, whereby a sudden impact can be applied to the occupant after termination of the EA function, which can result in insufficient effective absorption of an impact acted upon the occupant. On the other hand, in the event of a weak collision of the automotive vehicle, a tensile strength in excess of the prescribed value is not applied to the seatbelt, so that the EA function is not made effective, whereby impact absorption cannot be obtained.

[0008]

This invention has been proposed to solve the above-mentioned disadvantages, and the object of the invention is to provide an automotive passenger restraint and protection apparatus which is capable of properly protecting the occupant in the event of a collision of the automotive vehicle.

[0009]

In the second problem, the above conventional manner of fault diagnosis cannot always achieve accurate fault determination of the seatbelt locking mechanism.

[0010]

This invention has been proposed to solve the above-mentioned disadvantages, and the object of the invention is to provide an automotive passenger restraint and protection apparatus which is capable of performing accurate fault diagnosis of seatbelt locking means.

[0011]

[Means for Solving the Problems]

To attain the above object, an automotive passenger restraint and protection apparatus as claimed in claim 1 is provided, which has an electric retractor for retracting and protracting a seatbelt, an airbag device for causing expansion of an airbag to restrain an occupant, and a pretensioner for rapidly retracting the seatbelt to restrain the occupant, with

speed detecting means for detecting a speed of protraction of the seatbelt through the electric retractor, and control means for controlling at least one of actuation time of the airbag, expansion pressure of the airbag, actuation time of the pretensioner, a force of the pretensioner for retracting the seatbelt, and a force of the electric retractor for retracting the seatbelt, based upon the speed of protraction of the seatbelt detected by the speed detecting means.

[0012]

According to the construction of the present invention, the speed of protraction of the seatbelt is detected through the electric retractor, and at least one of actuation time of the airbag, expansion pressure of the airbag, actuation time of the pretensioner, a force of the pretensioner for retracting the seatbelt, and a force of the electric retractor for retracting the seatbelt is controlled, based upon the speed of protraction of the seatbelt detected by the speed detecting means. As a result, the occupant can be properly protected in the event of a collision of the automotive vehicle.

[0013]

The control means may control the actuation time of the airbag to shorten it when the speed of protraction of the seatbelt detected by the speed detecting means is high, and prolong it when the detected speed of protraction of the seatbelt is low.

[0014]

According to this construction, when the speed of protraction of the seatbelt detected by the speed detecting means is high, the actuation time of the airbag is shortened, i.e., the airbag quickly operates,and when the speed of protraction of the seatbelt detected by the speed detecting means is low, the actuation time of the airbag is prolonged, i.e., the airbag slowly operates. As a result, the occupant can be properly protected in a event of the collision of the automotive vehicle.

[0015]

The control means may control the expansion pressure of the airbag to decrease it when the speed of protraction of the seatbelt detected by the speed detecting means is high, and increase it when the detected speed of protraction of the seatbelt is low.

[0016]

According to this construction, when the protracting speed of the seatbelt is high, the expansion pressure of the airbag is decreased so as to reduce impact applied to the occupant, to thereby more properly protect the occupant in the event of a collision of the automotive vehicle. On the other hand, when the protracting speed of the seatbelt is low, the expansion pressure of the airbag is increased so as to set a moderate expansion pressure, to thereby more properly protect the occupant in the event of a collision of the automotive vehicle.

[0017]

The control means may control the actuation time of the pretensioner to shorten it when the speed of protraction of the seatbelt detected by the speed detecting means is high, and prolong it when the detected speed of protraction of the seatbelt is low.

[0018]

According to this construction, when the speed of protraction of the seatbelt detected by the speed detecting means is high, the actuation time of the pretensioner is shortened, i.e., the pretensioner quickly operates, and when the speed of protraction of the seatbelt detected by the speed detecting means is low, the actuation time of the pretensioner is prolonged, i.e., the pretensioner slowly operates. As a result, the occupant can be more properly protected in the event of a collision of the automotive vehicle.

[0019]

The control means may control the force of the

pretensioner for retracting the seatbelt to decrease it when the speed of protraction of the seatbelt detected by the speed detecting means is high, and increase it when the detected speed of protraction of the seatbelt is low.

[0020]

According to this construction, when the speed of protraction of the seatbelt detected by the speed detecting means is high, the force of the pretensioner for retracting the seatbelt is decreased so as to reduce impact applied to the occupant, to thereby more properly protect the occupant in the event of a collision of the automotive vehicle. On the other hand, when the speed of protraction of the seatbelt detected by the speed detecting means is low, the force of the pretensioner for retracting the seatbelt is increased so as to set a moderate retracting force of the seatbelt, to thereby more properly protect the occupant in the event of a collision of the automotive vehicle.

[0021]

The control means may control the force of the electric retractor for retracting the seatbelt to increase it when the speed of protraction of the seatbelt detected by the speed detecting means is high, and decrease it when the detected speed of protraction of the seatbelt is low.

[0022]

According to this construction, when the speed of protraction of the seatbelt detected by the speed detecting means is high, the force of the electric retractor for retracting the seatbelt is increased such that protraction of the seatbelt requires a large force, while when the speed of protraction of the seatbelt detected by the speed detecting means is low, the force of the electric retractor for retracting the seatbelt is decreased such that protraction of the seatbelt requires no large force. As a result, the protraction of the seatbelt is controlled so as to absorb impact applied to the occupant in the event of a collision of the automotive vehicle.

[0023]

To attain the above object, the automotive passenger restraint and protection apparatus as claimed in claim 2 may further include seatbelt locking means for locking the seatbelt from being protracted when the seatbelt is protracted at a predetermined or higher degree of the acceleration, and abnormality diagnosis means for carrying out a diagnosis as to abnormality of the seatbelt locking means by making a determination as to whether the seatbelt locking means has operated, in response to acceleration at which the seatbelt has been protracted.

[0024]

According to the construction of the present invention, abnormality diagnosis means carries out a diagnosis as to abnormality of the seatbelt locking means by making a determination as to whether the seatbelt locking means has operated, in response to acceleration at which the seatbelt has been protracted. As a result, accurate fault diagnosis of the seatbelt locking means can be performed.

[0025]

The automotive passenger restraint and protection apparatus as claimed in claim 2 may be further constructed such that the seatbelt locking means locks the seatbelt from being protracted when a predetermined or higher degree of acceleration is applied to an automotive vehicle, and the abnormality diagnosis means carries out a diagnosis as to abnormality of the seatbelt locking means by making a determination as to whether the seatbelt locking means has operated, in response to the acceleration applied to the automotive vehicle.

[0026]

According to this construction, the abnormality diagnosis means carries out a diagnosis as to abnormality of the seatbelt locking means by making a determination as to whether the seatbelt locking means has operated, in response to the

acceleration applied to the automotive vehicle. As a result, accurate fault diagnosis of the seatbelt locking means can be performed.

[0027]

Further, the abnormality diagnosis means may be constructed such that when a predetermined or higher degree of acceleration is applied to an automotive vehicle, if it is determined that the seatbelt locking means has operated, it is diagnosed that the seatbelt locking means is normal, and on the other hand, if it is determined that the seatbelt locking means has not operated, it is diagnosed that the seatbelt locking means is abnormal.

[0028]

According to this construction, more accurate fault diagnosis of the seatbelt locking means can be performed.

[0029]

Further, the abnormality diagnosis means may be constructed such that when a lower degree of acceleration than a predetermined degree is applied to an automotive vehicle, if it is determined that the seatbelt locking means has operated, it is diagnosed that the seatbelt locking means is abnormal, and on the other hand, if it is determined that the seatbelt locking means has not operated, it is diagnosed that the seatbelt locking means is normal.

[0030]

According to this construction, more accurate fault diagnosis of the seatbelt locking means can be performed.

[0031]

The automotive passenger restraint and protection apparatus as claimed in claim 2 may be constructed such that the automotive passenger restraint and protection apparatus further comprises driving means for driving the electric retractor, and driving signal supplying means for supplying the driving means with a first driving signal for protracting the seatbelt at the predetermined or higher degree of

acceleration, and supplying the driving means with a second driving signal for protracting the seatbelt at the lower degree of acceleration than the predetermined degree, and when each of the first and second driving signal is supplied, the abnormality diagnosis means carries out a diagnosis as to abnormality of the seatbelt locking means by making a determination as to whether the seatbelt locking means has operated.

[0032]

According to the construction of the present invention, the driving signal supplying means supplies the driving means with the first driving signal for protracting the seatbelt at the predetermined or higher degree of acceleration, and supplies the driving means with the second driving signal for protracting the seatbelt at the lower degree of acceleration than the predetermined degree, and when each of the first and second driving signal is supplied, the abnormality diagnosis means carries out a diagnosis as to abnormality of the seatbelt locking means by making the determination as to whether the seatbelt locking means has operated. As a result, accurate fault diagnosis of the seatbelt locking means can be performed. Further, the abnormality diagnosis is not carried out when only one driving signal is supplied, and when the two driving signal are both supplied, the abnormality diagnosis means carries out the diagnosis as to abnormality of the seatbelt locking means by making the determination as to whether the seatbelt locking means has operated. As a result, accurate fault diagnosis of the seatbelt locking means can be performed, based upon the results of the two determinations. More further, accurate fault diagnosis of the seatbelt locking means can be performed without breaking up the seatbelt locking means.

[0033]

Further, the abnormality diagnosis means may be constructed such that when the first driving signal is supplied, if it is determined that the seatbelt locking means has operated, it is diagnosed that the seatbelt locking means is

normal, and on the other hand, if it is determined that the seatbelt locking means has not operated, it is diagnosed that the seatbelt locking means is abnormal.

[0034]

According to this construction, the first driving signal for protracting the seatbelt at the predetermined or higher degree of acceleration is supplied. As a result, if it is determined that the seatbelt locking means has operated, it can be diagnosed that the seatbelt locking means is normal, and on the other hand, if it is determined that the seatbelt locking means has not operated, it can be diagnosed that the seatbelt locking means is abnormal.

[0035]

Further, the abnormality diagnosis means may be constructed such that when the second driving signal is supplied, if it is determined that the seatbelt locking means has operated, it is diagnosed that the seatbelt locking means is abnormal, and on the other hand, if it is determined that the seatbelt locking means has not operated, it is diagnosed that the seatbelt locking means is normal.

[0036]

According to this construction, the second driving signal for protracting the seatbelt at the lower degree of acceleration than the predetermined degree is supplied. As a result, if it is determined that the seatbelt locking means has operated, it can be diagnosed that the seatbelt locking means is abnormal, and on the other hand, if it is determined that the seatbelt locking means has not operated, it can be diagnosed that the seatbelt locking means is normal.

[0037]

Further, the abnormality diagnosis means may be constructed such that when the first driving signal is supplied, the abnormality diagnosis means carries out the diagnosis as to abnormality of the seatbelt locking means by making a determination as to whether the current flowing to the driving

means exceeds a predetermined value.

[0038]

According to this construction, the first driving signal for protracting the seatbelt at the predetermined or higher degree of the acceleration is supplied. Therefore, the protracting speed of the seatbelt becomes so high that the seatbelt locking means locks the seatbelt from being protracted, and then the current flowing to the driving means increases. As a result, if the current flowing to the driving means exceeds a predetermined value, it can be diagnosed that the seatbelt locking means is normal, and on the other hand, if the current flowing to the driving means is below a predetermined value, it can be diagnosed that the seatbelt locking means is abnormal.

[0039]

Further, the abnormality diagnosis means may be constructed such that when the second driving signal is supplied, the abnormality diagnosis means carries out the diagnosis as to abnormality of the seatbelt locking means by making a determination as to whether the current flowing to the driving means is below a predetermined value.

[0040]

According to this construction, the second driving signal for protracting the seatbelt at the lower degree of acceleration than the predetermined degree is supplied. Therefore, the protracting speed of the seatbelt becomes so low that the seatbelt locking means does not lock the seatbelt from being protracted, and then the current flowing to the driving means does not increase. As a result, if the current flowing to the driving means is below a predetermined value, it can be diagnosed that the seatbelt locking means is normal, and on the other hand, if the current flowing to the driving means exceeds a predetermined value, it can be diagnosed that the seatbelt locking means is abnormal.

[0041]

[Embodiments]

The invention will now be described in detail with reference to drawings showing embodiments thereof.

[0042]

[(1) First Embodiment]

Fig. 1 is a view showing the arrangement of an electric retractor 100 provided in an automotive passenger restraint and protection apparatus according to a first embodiment of the present invention.

[0043]

The electric retractor 100 has a frame 1 in which is rotatably mounted a reel shaft (take-up shaft) 3 for retracting and protracting a seatbelt 8, not shown. Secured to an end of the reel shaft 3 is a known seatbelt locking mechanism 2 which is adapted to lock or stop the seatbelt 8 from being protracted when a predetermined or higher degree of deceleration is applied to an automotive vehicle in which the present apparatus is installed or when the seatbelt 8 is protracted at a predetermined or higher degree of acceleration.

[0044]

The reel shaft 3 has a central shaft 3a coupled to a central shaft of a reel shaft pulley 5, which is in turn coupled to a DC motor pulley 6 via a power transmission belt 7. Provided inside the reel shaft pulley 5 is bias force-imparting means formed e.g. of a spiral spring which always applies a bias force to the pulley 5 in a direction of retraction of the seatbelt 8.

[0045]

The reel shaft pulley 5 and the DC motor pulley 6 each have an outer periphery thereof formed with a predetermined number of outer teeth, while the power transmission belt 7 has an inner periphery thereof formed with a predetermined number of inner teeth which are in mesh with the outer teeth of the reel shaft pulley 5 and the DC motor pulley 6.

[0046]

The DC motor pulley 6 has a central shaft thereof coupled

to a DC motor 10 such that the rotation of the DC motor 10 is transmitted to the reel shaft 3 via the DC motor pulley 6.

[0047]

The DC motor 10 is fixed to the frame 1 at at least two points, and is electrically connected to an MPU (Micro Processing Unit) 14 via a DC motor driver 11.

[0048]

The DC motor driver 11 controls the rotation of the DC motor 10, based upon a control signal from the MPU 14.

[0049]

Fig. 2 is a circuit diagram showing the construction of the DC motor driver 11. In Fig. 2, terminals P1 and P2 are input terminals for a control signal output from the MPU 14, terminals P3 and P4 are output terminals for detecting current, and terminals P5 and P6 are output terminals for detecting voltage, and the terminals P1 to P6 are connected to the MPU 14. In Fig. 2, circuit C1 is a current detecting circuit which detects current i flowing to the DC motor 10, based upon current flowing through a resistance r1, and circuit C2 is a voltage measuring circuit which measures terminal voltage across the DC motor 10. A plurality of transistors and FETs appearing in Fig. 2 are for selectively changing the DC motor 10 to be normally rotated or reversely rotated in response to a control signal from the MPU 14.

[0050]

When the control signal is input through the terminal P1 by the MPU 14, the DC motor 10 normally rotates and the seatbelt 8 is retracted through the reel shaft 3. On the other hand, when the control signal is input through the terminal P2 by the MPU 14, the DC motor 10 reversely rotates and the seatbelt 8 is protracted through the reel shaft 3.

[0051]

The reel shaft 3 is connected to the DC motor 10 via the reel shaft pulley 5, the power transmission belt 7 and the DC motor pulley 6, and therefore the rotational speed of the reel

shaft 3 is proportional to the terminal voltage across the DC motor 10 with its terminals open.

[0052]

The MPU 14 controls such that the control signal in not applied to the terminals P1 and P2 at the same time.

[0053]

Referring back to Fig. 1, the MPU 14 is connected to a buckle connection detector 16 which detects whether a tongue of the seatbelt 8 has been attached to or mounted on the buckle and whether the tongue of the seatbelt 8 has been disconnected from the buckle. The MPU 14 has a built-in timer 15 for measuring time. Moreover, the MPU 14 determines whether the seatbelt 8 has been protracted, based upon the sign of the terminal voltage of the DC motor 10 and determines whether the retraction of the seatbelt 8 has been terminated, based upon the current flowing to the DC motor 10.

[0054]

The buckle connection detector 16 detects whether a tongue of the seatbelt has been attached to or mounted on the buckle and whether the tongue of the seatbelt has been disconnected from the buckle and delivers a control signal indicative of results of the detections to the MPU 14.

[0055]

Then, the MPU 14 is connected to the airbag and pretensioner controller 17 which controls the airbag 18 and the pretensioner 19, hereinafter referred to. The airbag and pretensioner controller 17 is connected to the airbag 18 and the pretensioner 19 which operate to prevent the occupant from colliding against equipment within the vehicle compartment upon a collision of the vehicle.

[0056]

The airbag 18 has a plurality of gas generators 20. The pretensioner 19 rapidly winds up the seatbelt to protect the occupant upon a collision of the vehicle and has a plurality of gas generators 21. The pretensioner 19 is coupled to the

central shaft 3s of the reel shaft 3 via the reel shaft pulley 5.

[0057]

Fig. 3 is a view showing the construction of the pretension 19. The pretensioner 19 is comprised of a gas chamber 30 in which a gas generated from the gas generators 21, not shown in Fig. 3, is enclosed, a pinion 32 coupled to the central shaft 3a of the reel shaft 3 and has an outer periphery thereof formed with a predetermined number of outer teeth, and a rack 31 having an end portion thereof formed with inner teeth disposed in mesh with the outer teeth of the pinion 32 and the other end portion slidably fitted in a gas-tight manner and defining the gas chamber 30.

[0058]

When gas generated from the gas generators 21, not shown in Fig. 3, is introduced into the gas chamber 30, as the gas is sealed with the rack 31, the pressure within the gas chamber 30 rises to urgingly move the rack 31 downward. This causes the pinion 32 to rotate in unison with the movement of the rack 31 to cause the reel shaft 3 coupled to the pinion 32 to rotate in the seatbelt retracting direction, whereby the seatbelt is rapidly retracted upon a collision of the vehicle.

[0059]

Referring again to Fig. 1, the airbag and pretensioner controller 17 receives a pressure control signal and a timing control signal from the MPU 14, and in response to these control signals, sets and changes the actuation time and expansion pressure of the airbag 18 or the actuation time of the pretensioner 19, and the force of the pretensioner 19 for retracting the seatbelt.

[0060]

Fig. 4 is a flowchart showing details of airbag and seatbelt driving control executed by the MPU 14 according to the present embodiment upon a collision of the automotive vehicle. The airbag and seatbelt driving control forms a part of a main control executed by the MPU 14.

[0061]

First, it is determined at a step S41 whether attaching of the seatbelt tongue to the buckle has been detected by the buckle connection detector 16. If attaching of the seatbelt 8 has not been detected, the present processing is immediately terminated, whereas if attaching of the seatbelt 8 has been detected, it is determined at a step S42 whether the seatbelt 8 has been protracted. The MPU 14 determines whether the seatbelt 8 has been protracted, based upon the sign of the terminal voltage of the DC motor 10.

[0062]

If it is determined at the step S42 that the seatbelt 8 has not been protracted, the present processing is immediately terminated, whereas if the seatbelt 8 has been protracted, the rotational speed of the reel shaft 3 is detected at a step S43. The rotational speed of the reel shaft 3 is proportional to the terminal voltage across the DC motor 10 with its terminals open, and therefore the rotational speed of the reel shaft 3 is detected based upon the terminal voltage across the DC motor 10.

[0063]

Then, it is determined at a step S44 whether the detected rotational speed of the reel shaft 3 is higher than a predetermined value (e.g. 5 revolutions per sec). If the former is not higher than the latter, it means that the occupant has moved after attaching the seatbelt onto his body, and therefore the present processing is immediately terminated. On the other hand, if the reel shaft speed is higher than the predetermined value, it means that the vehicle has collided, a correction value T1 for the actuation times of the the airbag 18 and the pretensioner 19 is calculated by the use of the following formula (1) and a correction value P1 for the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19 by the use of the following formula (2), at a step S45. The timer 15 starts measuring time elapsed after the collision of the vehicle. Then, the following formula (1) is a

formula for calculating the correction value T1 for the actuation times of the the airbag 18 and the pretensioner 19 and the following formula (2) is a formula for calculating the correction value P1 for the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19.

[0064]

[Formula 1]

$$T1 = K2\ (1 - K1 \times 1/v) \cdots \quad (1)$$

T1 : the correction value for the actuation times of the the airbag 18 and the pretensioner 19

K2 : a second coefficient ($K2 > 0$)

K1 : a first coefficient ($K1 > 0$)

v : the rotational speed of the reel shaft 3

$$P1 = a2\ (1 - a1 \times 1/v) \cdots \quad (2)$$

P1 : the correction value for the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19

a2 : second coefficient ($a2 > 0$)

a1 : first coefficient ($a1 > 0$)

v : the rotational speed of the reel shaft 3

Then, signals indicative of the correction values calculated based upon the above formulas (1) and (2) are delivered to the airbag and pretensioner controller 17 at a step S46.

[0065]

According to the above formulas (1) and (2), in the event of a strong collision of the vehicle, the reel shaft rotational speed v is high so that the calculated correction value T1 of the actuation times of the airbag 18 and the pretensioner 19 is large (long) and also the calculated correction value P1 of the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19 is large. On the other hand, in the event of a weak collision of the vehicle, the reel shaft rotational speed v is low so that the calculated correction value T1 of the actuation times of the airbag 18 and the

pretensioner 19 is small (short) and also the calculated correction value P1 of the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19 is small.

[0066]

Then, the airbag and pretentioner controller 17 calculates a desired value T of the actuation times of the airbag 18 and the pretensioner 19 by the use of the following formula (3), and actuates the gas generators 20 and 21 of the airbag 18 and the pretensioner 19 based upon the calculated desired actuation time value T.

[0067]

Further, the airbag and pretensioner controller 17 calculates a desired value P of the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19 by the use of the following formula (4), and actuates the gas generators 20 and 21 of the airbag 18 and the pretensioner 19 based upon the calculated desired value P.

[0068]

[Formula 2]

$T = T2 - T1 \cdots$ (3)

T : the actuation times of the airbag 18 and the pretensioner 19

T2 : a predetermined value of the actuation times of the airbag 18 and the pretensioner 19

$P = P2 - P1 \cdots$ (4)

P : the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19

P2 : a predetermined value of the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19

According to the above formula (3), in the event of a strong collision of the vehicle, the calculated correction value T1 of the actuation times of the airbag 18 and the pretensioner 19 is long from the above formula (1), and

accordingly the calculated actuation time T of the airbag 18 and the pretensioner 19 is short. Therefore, the airbag and pretensioner controller 17 sets the igniting timing of the gas generators 20 and 21 to advanced timing. By thus controlling, even in the case where the protracting speed of the seatbelt is so high that the occupant is very likely to collide against equipment within the vehicle compartment, the airbag 18 and the pretensioner 19 are quickly actuated to properly protect the occupant. On the other hand, in the event of a weak collision of the vehicle, the calculated correction value T1 of the actuation times of the airbag 18 and the pretensioner 19 is short from the above formula (1), and accordingly the calculated actuation time T of the airbag 18 and the pretensioner 19 is long. Therefore, the airbag and pretensioner controller 17 sets the igniting timing of the gas generators 20 and 21 to relatively retarded timing. By thus controlling, in the event of a weak collision of the vehicle, the igniting timing of the gas generators can be set to a retarded value than in the conventional apparatus to thereby give an appropriate amount of impact to the occupant and hence properly protect the occupant in the event of a collision of the vehicle.

[0069]

According to the above formula (4), in the event of a strong collision of the vehicle, the calculated correction value P1 of the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19 is large from the above formula (2), and accordingly the calculated desired value P of the expansion pressure and seatbelt retracting force is small. Therefore, the airbag and pretensioner controller 17 actuates only one gas generator if two gas generators are actuated in the event of a collision of the vehicle in the conventional automotive passenger restraint and protection apparatus, so as to decrease the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19 to a smaller value than in the conventional automotive

passenger restraint and protection apparatus, whereby impact applied to the occupant is reduced. On the other hand, in the event of a weak collision of the vehicle, the calculated correction value P1 of the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19 is small from the above formula (2), and accordingly the calculated desired value P of the expansion pressure and seatbelt retracting force is large. Therefore, the airbag and pretensioner controller 17 actuates three gas generators so as to increase the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19 to a larger value than in the conventional automotive passenger restraint and protection apparatus. By thus controlling, in the event of a weak collision of the vehicle, the expansion pressure of the airbag and the seatbelt retracting force of the pretensioner can be set to a larger value than in the conventional apparatus to thereby give an appropriate magnitude of pressure and force to the occupant and hence properly protect the occupant in the event of a collision of the vehicle.

[0070]

By virtue of the control according to the steps S45 and S46 and the formulas (1) to (4), even in the event that the protracting speed of the seatbelt 8 is so high that the occupant is very likely to collide against equipment within the vehicle compartment, the airbag 18 and the pretensioner 19 quickly operate to properly protect the occupant upon a collision of the vehicle. Further, the desired value P of the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19 can be set to a smaller value than in the conventional apparatus, to thereby reduce impact applied to the occupant and hence properly protect the occupant upon a collision of the vehicle.

[0071]

Further, when the protracting speed of the seatbelt is low, the igniting timing of the gas generators can be set to a

retarded value than in the conventional apparatus to thereby give an appropriate amount of impact to the occupant, and the expansion pressure of the airbag and the seatbelt retracting force of the pretensioner can be set to a larger value than in the conventional apparatus, to thereby reduce impact applied to the occupant and hence properly protect the occupant upon a collision of the vehicle.

[0072]

Then, a correction value F1 of the driving force of the reel shaft 3 for retracting the seatbelt is calculated by the use of the following formula (5), at a step S47. The following formula (5) is a formula for calculating a correction value F1 of the driving force of the reel shaft 3 for retracting the seatbelt 8.

[0073]

[Formula 3]

$F1 = b2\ (1 - b1 \times v) \cdots \quad (5)$

F1 : the correction value of the driving force of the reel shaft 3 for retracting the seatbelt 8

b2 : a second coefficient ($B2 > 0$)

b1 : a first coefficient ($b1 > 0$)

v : the rotational speed of the reel shaft 3

$F = F2 - F1 \cdots \quad (6)$

F : the driving force of the reel shaft 3 for retracting the seatbelt 8

F2 : a predetermined value of the driving force of the reel shaft 3

According to the above formula (5), in the event of a strong collision of the vehicle, the rotational speed v of the reel shaft 3 is high, and accordingly the calculated correction value F1 of the driving force of the reel shaft 3 is small, and on the other hand, in the event of a weak collision of the vehicle, the rotational speed v of the reel shaft 3 is low, and accordingly the calculated correction value F1 is large.

[0074]

Then, a desired driving force F of the reel shaft 3 is calculated by the use of the following formula (6) and the airbag and pretensioner controller 17 drives the reel shaft 3 based upon the calculated driving force F, at a step S48. To drive the reel shaft 3 with the driving force F, the MPU 14 sets the duty factor of a control signal to be delivered to the DC motor driver 11 to set the terminal voltage across the DC motor 10.

[0075]

According to the above formula (6), in the event of a strong collision of the vehicle, the calculated correction value F1 of the driving force of the reel shaft 3 for retracting the seatbelt is small from the above formula (5), and accordingly the calculated desired driving force F of the reel shaft 3 for retracting the seatbelt is large. Therefore, the EA function, which causes the reel shaft to rotate in the direction of protracting the seatbelt when a tension in excess of a prescribed value is applied to the seatbelt immediately after a collision of the automotive vehicle, can operate to protract the seatbelt without being terminated halfway, i.e. at a time point when it is desired that the same function should be still exhibited, since a substantial tension applied to the seatbelt is reduced by the large driving force F of the reel shaft 3. Thus, the EA function can effectively absorb impact applied to the occupant to thereby properly protect the occupant in the event of a strong collision of the vehicle. On the other hand, in the event of a weak collision of the vehicle, the calculated correction value F1 of the driving force of the reel shaft 3 for retracting the seatbelt is large from the above formula (5), and accordingly the calculated desired driving force F of the reel shaft 3 for retracting the seatbelt is small. Therefore, the EA function can operate to protract the seatbelt without fail, since a substantial tension applied to the seatbelt is increased by the small driving force of the reel shaft 3. Thus, the EA function can effectively absorb impact applied to the occupant to thereby properly protect the occupant in the event of a weak

collision of the vehicle.

[0076]

Next, it is determined at a step S49 whether a predetermined time period (e.g. 2 sec) has elapsed after the collision, based upon the value of the timer 15. If the predetermined time period has not elapsed, the same determination is repeated, whereas if the predetermined time period has elapsed, the driving of the reel shaft 3 is stopped at a step S50, followed by terminating the present processing. To stop the driving of the reel shaft, the MPU 14 delivers a control signal commanding to stop the driving of the DC motor 10 to the DC motor driver 11.

[0077]

As described above, according to the first embodiment, the desired value T of the actuation times of the airbag 18 and the pretensioner 19, and the desired value P of the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19 are variably set according to the terminal voltage across the DC motor 10 with its terminals open and the rotational speed v of the reel shaft 3 (steps S45 and S46, and formulas (1) to (4)). As a result, even when the protracting speed of the seatbelt 8 is so high that the occupant is very likely to collide again equipment within the vehicle compartment, as in the event of a strong collision of the vehicle, the airbag 18 and the pretensioner 19 can be quickly actuated, and further the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19 are set to a smaller value to thereby reduce impact applied to the occupant and hence properly protect the occupant in the event of a collision of the vehicle.

[0078]

Further, when the retracting speed of the seatbelt 8 is low as in the event of a weak collision of the vehicle, the igniting timing of the gas generators can be set to a retarded value than in the conventional apparatus to thereby give an

appropriate amount of impact to the occupant, and further the expansion pressure of the airbag and the seatbelt retracting force of the pretensioner can be set to a larger value than in the conventional apparatus, to thereby reduce impact applied to the occupant and hence properly protect the occupant upon a collision of the vehicle.

[0079]

Furthermore, the driving force F of the reel shaft 3 for retracting the seatbelt 8 can be variably set according to the terminal voltage across the DC motor 10 with its terminals open or the rotational speed v of the reel shaft 3 (steps S47 and S48, and formulas (5) and (6)). As a result, impact applied to the occupant can be effectively absorbed to thereby properly protect the occupant in the event of a collision of the vehicle.

[0080]

Although in the present embodiment the rotational speed v of the reel shaft 3 is detected from the terminal voltage of the DC motor 10 with its terminals open, this is not limitative, but alternatively the rotational speed v of the reel shaft 3 may be detected by a rotational speed sensor which may be provided on the central shaft 3a of the reel shaft 3.

[0081]

Further, although in the present embodiment the rotational speed v of the reel shaft 3 is used for the above described control, alternatively a retracting speed sensor may be provided at an outlet port for the seatbelt to thereby directly detect the protracting speed of the seatbelt, providing substantially the same results.

[0082]

[(2) Second Embodiment]

Fig. 5 is a view showing the arrangement of an electric retractor 200 provided in an automotive passenger restraint and protection apparatus according to a second embodiment of the invention.

[0083]

The electric retractor 200 has a frame 201 in which is rotatably mounted a reel shaft (take-up shaft) 203 for retracting and protracting a seatbelt 208, not shown. Secured to an end of the reel shaft 203 is a known seatbelt locking mechanism 202 which is adapted to lock or stop the seatbelt 208 from being protracted when a predetermined or higher degree of deceleration is applied to an automotive vehicle in which the present apparatus is installed or when the seatbelt 208 is protracted at a predetermined or higher degree of acceleration.

[0084]

The reel shaft 203 has a central shaft 203a coupled to a central shaft of a reel shaft pulley 205, which is in turn coupled to a DC motor pulley 206 via a power transmission belt 207. Provided inside the reel shaft pulley 205 is bias force-imparting means formed e.g. of a spiral spring which always applies a bias force to the pulley 205 in a direction of retraction of the seatbelt 208.

[0085]

The reel shaft pulley 205 and the DC motor pulley 206 each have an outer periphery thereof formed with a predetermined number of outer teeth, while the power transmission belt 207 has an inner periphery thereof formed with a predetermined number of inner teeth which are in mesh with the outer teeth of the reel shaft pulley 205 and the DC motor pulley 206.

[0086]

The DC motor pulley 206 has a central shaft thereof coupled to a DC motor 210 such that the rotation of the DC motor 210 is transmitted to the reel shaft 203 via the DC motor pulley 206.

[0087]

The DC motor 210 is fixed to the frame 201 at at least two points, and is electrically connected to an MPU (Micro Processing Unit) 214 via a DC motor driver 211.

[0088]

The DC motor driver 211 controls the rotation of the DC

motor 210, based upon a control signal from the MPU 214.

[0089]

Fig. 6 is a circuit diagram showing the construction of the DC motor driver 211. In Fig. 6, terminals P11 and P12 are input terminals for a control signal output from the MPU 214, terminals P13 and P14 are output terminals for detecting current, and terminals P15 and P16 are output terminals for detecting voltage, and the terminals P11 to P16 are connected to the MPU 214. In Fig. 6, circuit C11 is a current detecting circuit which detects current i flowing to the DC motor 210, based upon current flowing through a resistance r11, and circuit C12 designates a voltage measuring circuit which measures terminal voltage across the DC motor 210. A plurality of transistors and FETs appearing in Fig. 6 are for selectively changing the DC motor 210 to be normally rotated or reversely rotated in response to a control signal from the MPU 214.

[0090]

When the control signal is input through the terminal P11 by the MPU 214, the DC motor 210 normally rotates and the seatbelt 208 is retracted through the reel shaft 203. On the other hand, when the control signal is input through the terminal P12 by the MPU 214, the DC motor 210 reversely rotates and the seatbelt 208 is protracted through the reel shaft 203.

[0091]

When a duty factor of the control signal is increased by the MPU 214 and the control signal is input through the terminal P11, a degree of rotational acceleration of the DC motor 10 is increased. On the other hand, when the duty factor of the control signal is decreased and the control signal is input through the terminal P11, a degree of rotational acceleration of the DC motor 10 is decreased.

[0092]

The reel shaft 203 is connected to the DC motor 210 via the reel shaft pulley 205, the power transmission belt 207 and the DC motor pulley 206, and therefore the rotational speed of

the reel shaft 203 is proportional to the terminal voltage across the DC motor 210 with its terminals open.

[0093]

The MPU 214 controls such that the control signal in not applied to the terminals P11 and P12 at the same time.

[0094]

In the automotive passenger restraint and protection apparatus constructed as above, a summary of control processing (fault diagnosis) executed by the MPU 214 will be described below.

[0095]

The fault diagnosis according to the present embodiment is carried out by the following two methods (a) and (b) which are executed independently of each other, and when it is determined by either one of the methods that there is a fault, it is judged that the seatbelt locking mechanism 202 is faulty:

(a) When no fault in the seatbelt 208 locking mechanism 202 is detected, it is checked whether the seatbelt locking mechanism 202 functions normally while the reel shaft 203 is given a rotational speed in the seatbelt protracting direction at which the seatbelt 208 can be locked during protraction, and if the mechanism 202 does not function normally, it is determined that there is a fault.

[0096]

(b) When no fault in the seatbelt locking mechanism 202 is detected, it is checked whether the seatbelt locking mechanism 202 does not function while the reel shaft 203 is given a rotational speed in the seatbelt protracting direction at which the seatbelt 208 cannot be locked during protraction, and if the mechanism 202 functions, it is determined that there is a fault.

[0097]

Details of the control processing will now be described with reference to Figs. 7 and 8. Fig. 7 is a flowchart showing an example of a fault diagnostic program executed by the MPU 214, which corresponds to the method (a).

[0098]

First, to quickly protract the seatbelt 208 in attaching the seatbelt 208 to the occupant's body, a control signal commanding to rotate the DC motor 210 in the seatbelt protracting direction at a high speed, i.e. a control signal having a duty factor required for such a high speed rotation, is delivered to the DC motor driver 211 at a step S301. Responsive to this control signal, the DC motor driver 211 rotates the DC motor 210 at a high rotational speed in the seatbelt protracting direction. The reel shaft 203 is connected to the DC motor 210 via the reel shaft pulley 205, the power transmission belt 207 and the DC motor pulley 206, and therefore rotates in the seatbelt protracting direction at a high speed in unison with the rotation of the DC motor 210. If the seatbelt locking mechanism 202 is normal, it locks the reel shaft 203 to stop when the latter rotates at the above high speed.

[0099]

Then, the current i flowing to the DC motor 210 is detected, based upon current flowing through the resistance r11 by the current detecting circuit C11 of the DC motor driver 211 at a step S302. It is determined at a step S303 whether the detected current i exceeds a predetermined value (e.g. 5 amperes).

[0100]

If the detected current i exceeds the predetermined value, that is, the DC motor 210 continues to be energized for rotation with the reel shaft 203 in the locked state, it is determined at a step S304 that the seatbelt locking mechanism 202 is functioning normally, followed by terminating the present processing.

[0101]

On the other hand, if the detected current i is below the predetermined value, that is, the DC motor 210 continues to be energized for rotation with the reel shaft 203 not properly locked, it is determined at a step S305 that the seatbelt locking

mechanism 202 is functioning abnormally, and then a warning is given to the occupant by means of a display device or a warning light (not shown) to warn him of the abnormality of the seatbelt locking mechanism 202 at a step S306, followed by terminating the present processing.

[0102]

Fig. 8 is a flowchart showing an example of a fault diagnostic program executed by the MPU 214, which corresponds to the method (b).

[0103]

First, to slowly protract the seatbelt 208 to give a predetermined amount of looseness to the seatbelt 208 after the seatbelt 208 is attached to the occupant and made fit to his body, a control signal commanding to rotate the DC motor 210 in the seatbelt protracting direction at a low speed, i.e. a control signal having a duty factor required for such a low speed rotation, is delivered to the DC motor driver 211 at a step S401. Responsive to this control signal, the DC motor driver 211 rotates the DC motor 210 at a low speed in the seatbelt protracting direction. The reel shaft 203 is connected to the DC motor 210 via the reel shaft pulley 205, the power transmission belt 207 and the DC motor pulley 206, and therefore rotates in the seatbelt protracting direction at a low speed in unison with the rotation of the DC motor 210. If the seatbelt locking mechanism 202 is normal, it does not lock the reel shaft 203 when the latter rotates at the above low speed.

[0104]

Then, the current i flowing to the DC motor 210 is detected, based upon current flowing through the resistance r11 by the current detecting circuit C11 of the DC motor driver 211 at a step S402. It is determined at a step S403 whether the detected current i is below a predetermined value (e.g. 3 amperes).

[0105]

If the detected current i is below the predetermined

value, that is, the DC motor 210 continues to be energized for rotation with the reel shaft 203 in the unlocked state, it is determined at a step S405 that the seatbelt locking mechanism 202 is functioning normally, followed by terminating the present processing.

[0106]

On the other hand, if the detected current i exceeds the predetermined value, that is, the DC motor 10 continues to be energized for rotation with the reel shaft 203 in the locked state, it is determined at a step S404 that the seatbelt locking mechanism 202 is functioning abnormally.

[0107]

And then a warning is given to the occupant by means of the display device or the warning light to warn him of the abnormality of the seatbelt locking mechanism 202 at a step S406, followed by terminating the present processing.

[0108]

In the present control processing (fault diagnosis), only when it is determined at both of the steps S304 and S405 in Figs. 7 and 8 that the seatbelt locking mechanism 202 is functioning normally, it is finally determined that the same mechanism is normal, while when it is determined at either the step S305 in Fig. 7 or the step S404 in Fig. 8 that the seatbelt locking mechanism 202 is functioning abnormally, it is immediately finally determined that the same mechanism is abnormal.

[0109]

As describe above, according to the second embodiment, after a control signal commanding to rotate the DC motor 210 in the seatbelt protracting direction at a high speed, i.e. a control signal having a duty factor required for such a high speed rotation, is delivered to the DC motor driver 211 at the step S301, the current i flowing to the DC motor 210 is detected at the step S302, and It is determined at the step S303 whether the detected current i exceeds a predetermined value, and then

it is determined at the steps S304 and S305 that the seatbelt locking mechanism 202 is normal or abnormal based upon the result of the determination. Further, after a control signal commanding to rotate the DC motor 210 in the seatbelt protracting direction at a low speed, i.e. a control signal having a duty factor required for such a low speed rotation, is delivered to the DC motor driver 211 at the step S401, the current i flowing to the DC motor 210 is detected at the step S402, and It is determined at the step S403 whether the detected current i is below a predetermined value, and then it is determined at the steps S404 and S405 that the seatbelt locking mechanism 202 is normal or abnormal based upon the result of the determination. Further, the abnormality of the seatbelt locking mechanism is finally determined based upon the above two determinations. As a result, fault diagnosis of the seatbelt locking mechanism 202 can be accurately achieved.

[0110]

Further, since the results of the determinations (steps S305, S404 and S405) are notified via the display device or warning light (steps S306 and S406). As a result, the occupant can understand the cause of the fault.

[0111]

Although in the present embodiment fault diagnosis is made based upon results of the two kinds of determinations, a plurality of kinds of control signals commanding different high rotational speeds, for example, and/or a plurality of kinds of control signals commanding different low rotational speeds, for example, may be delivered to the DC motor driver to carry out fault diagnosis based upon more than two kinds of determinations.

[0112]

[(3) Third Embodiment]

An automotive passenger restraint and protection apparatus according to a third embodiment of the invention includes an electric retractor which is identical in

construction with the electric retractor 200 of the above described second embodiment. The third embodiment is distinguished from the second embodiment in the manner of fault diagnosis.

[0113]

A summary of control processing (fault diagnosis) executed by the MPU 214 according to the present embodiment will be first described below.

[0114]

The fault diagnosis according to the present embodiment is carried out by the following two methods (c) and (d) which are executed independently of each other, and when it is determined by either one of the methods that there is a fault, it is judged that the seatbelt locking mechanism 202 is faulty:

(c) When no fault in the seatbelt locking mechanism 202 is detected, it is checked whether the seatbelt locking mechanism 202 functions normally while the reel shaft 203 is given a rotational acceleration in the seatbelt protracting direction at which the seatbelt 208 can be locked during protraction, and if the mechanism 202 does not function normally, it is determined that there is a fault.

[0115]

(d) When no fault in the seatbelt locking mechanism 202 is detected, it is checked whether the seatbelt locking mechanism 202 does not function while the reel shaft 203 is given a rotational acceleration in the seatbelt protracting direction at which the seatbelt 208 cannot be locked during protraction, and if the mechanism 202 functions, it is determined that there is a fault.

[0116]

Details of the control processing will now be described with reference to Figs. 9 and 11. Fig. 9 is a flowchart showing an example of a fault diagnostic program executed by the MPU 14, which corresponds to the method (c).

[0117]

First, to quickly protract the seatbelt 208 in attaching the seatbelt 208 on the occupant's body, a control signal commanding to rotate the DC motor 210 in the seatbelt protracting direction at a high rotational speed, i.e. a control signal commanding a change from a low degree of rotational acceleration to a desired high degree of rotational acceleration, is delivered to the DC motor driver 211 at a step S501. More specifically, the MPU 214 gradually increases the duty factor of the control signal, and responsive to this control signal, the DC motor driver 211 changes the rotational acceleration of the DC motor 210 from a low degree of rotational acceleration to a high degree of rotational acceleration in the seatbelt protracting direction. The reel shaft 203 then gradually increases in rotational acceleration in the seatbelt protracting direction in unison with the rotational acceleration of the DC motor 210. If the seatbelt locking mechanism 202 is normal, it locks the reel shaft 203 when the rotational acceleration of the reel shaft changes from the low degree of rotational acceleration to the desired high degree of rotational acceleration.

[0118]

Then, the current i flowing to the DC motor 210 is detected, based upon current flowing through the resistance r11 by the current detecting circuit C11 of the DC motor driver 211 at a step S502. It is determined at a step S503 whether the detected current i exceeds a predetermined value (e.g. 5 amperes).

[0119]

If the detected current i exceeds the predetermined value, that is, the DC motor 210 continues to be energized for rotation with the reel shaft 203 in the locked state, the duty factor of the control signal delivered from the MPU 214 to the DC motor driver 211 is detected at a step S504.

[0120]

Then, it is determined at a step S505 whether the detected

duty factor falls within a range between a first predetermined value (e.g. 60 %) and a second predetermined value (e.g. 70 %). This is for determining whether the duty factor of the control signal is included within a range of duty factor within which the duty factor should fall in changing the rotational acceleration of the DC motor 210 from the low degree of rotational acceleration to the desired high degree of rotational acceleration when the seatbelt locking mechanism 202 functions normally.

[0121]

If it is determined that the duty factor falls within the above range, the duty factor of the control signal is included within the range of duty factor within which the duty factor should fall in changing the rotational acceleration of the DC motor 210 from the low degree of rotational acceleration to the desired high degree of rotational acceleration, and therefore it is determined at a step S506 that the seatbelt locking mechanism 202 is normal, followed by terminating the present processing.

[0122]

On the other hand, if it is determined that the duty factor does not fall within the range between the first predetermined value and the second predetermined value, the duty factor of the control signal is not included within the range of duty factor within which the duty factor should fall in changing the rotational acceleration of the DC motor 210 from the low degree of rotational acceleration to the desired high degree of rotational acceleration, and therefore it is determined at a step S507 that the seatbelt locking mechanism 220 is abnormal, and then a warning is given to the occupant by means of a display device or a warning light (not shown) to warn him of the abnormality of the seatbelt locking mechanism 202 at a step S508, followed by terminating the present processing.

[0123]

If it is determined at the step S503 that the detected

current i is below the predetermined value, that is, the DC motor 210 continues to be energized for rotation with the reel shaft 203 in the unlocked state, the duty factor of the control signal is further increased at a step S509.

[0124]

Then, it is determined at a step S510 whether the duty factor of the control signal is the maximum, i.e. 100 %, and if it is the maximum, the processing proceeds to the step S505, whereas if it is not the maximum, the processing returns to the step S502.

[0125]

Fig. 10 is showing a view of the relationship between the duty factor of the control signal and time elapsed after the start of delivery of the control signal.

[0126]

In the figure, a point A represents a duty factor detected at the step S504 after it is determined at the step S503 that the detected current i exceeds the predetermined value (e.g. 5 amperes). The duty factor at the point A is 65 % which falls within the range between the first and second predetermined values (60 - 70 %) (the answer is YES at the step S505). Therefore, in this case, the duty factor of the control signal is included within the range of duty factor within which the duty factor should fall in changing the rotational acceleration of the DC motor 210 from the low degree of rotational acceleration to the desired high degree of rotational acceleration, and therefore it is determined that the seatbelt locking mechanism 202 is normal (step S506).

[0127]

On the other hand, a point B represents a duty factor detected at the step S504 after it is determined at the step S503 that the detected current i is below the predetermined value (5 amperes), then the duty factor is increased (step S509), again the current i is detected (step S510) and it is determined that the detected current i exceeds the predetermined value. The

duty factor at the point B is 80 % which falls out of the range between the first and second predetermined values (the duty factor is below 60% or exceeds 70 %). Therefore, in this case, the duty factor of the control signal is not included within the range of duty factor within which the duty factor should fall in changing the rotational acceleration of the DC motor 210 from the low degree of rotational acceleration to the desired high degree of rotational acceleration, and therefore it is determined that the seatbelt locking mechanism 202 is abnormal (step S507).

[0128]

Fig. 11 is a flowchart showing an example of a fault diagnostic program executed by the MPU 214, which corresponds to the method (d).

[0129]

First, to slowly protract the seatbelt 208 to give a predetermined amount of looseness to the seatbelt 208 after the seatbelt 208 is attached to the occupant and made fit to his body, a control signal commanding to rotate the DC motor 210 in the seatbelt protracting direction at a low speed, i.e. a control signal commanding a change from a high degree of rotational acceleration to a desired low degree of rotational acceleration, is delivered to the DC motor driver 11 at a step S701. More specifically, the MPU 214 gradually decreases the duty factor of the control signal, and responsive to this control signal, the DC motor driver 211 changes the rotational acceleration of the DC motor 210 from a high degree of rotational acceleration to a low degree of rotational acceleration in the seatbelt protracting direction. The reel shaft 203 then gradually decreases in rotational acceleration in the seatbelt protracting direction in unison with the rotational acceleration of the DC motor 210. If the seatbelt locking mechanism 2 is normal, it does not lock the reel shaft 203 when the rotational acceleration of the reel shaft changes from the high degree of rotational acceleration to the desired low degree

of rotational acceleration.

[0130]

Then, the current i flowing to the DC motor 210 is detected, based upon current flowing through the resistance r11 by the current detecting circuit C11 of the DC motor driver 211 at a step S702. It is determined at a step S703 whether the detected current i is below a predetermined value (e.g. 5 amperes).

[0131]

If the detected current i is below the predetermined value at the step S703, that is, the DC motor 210 continues to be energized for rotation with the reel shaft 203 in the unlocked state, the duty factor of the control signal delivered from the MPU 214 to the DC motor driver 211 is detected at a step S704.

[0132]

Then, it is determined at a step S705 whether the detected duty factor falls within a range between a first predetermined value (e.g. 30 %) and a second predetermined value (e.g. 40 %). This is for determining whether the duty factor of the control signal is included within a range of duty factor within which the duty factor should fall in changing the rotational acceleration of the DC motor 210 from the high degree of rotational acceleration to the desired low degree of rotational acceleration when the seatbelt locking mechanism 202 functions normally.

[0133]

If it is determined that the duty factor falls within the above range, the duty factor of the control signal is included within a range of duty factor within which the duty factor should fall in changing the rotational acceleration of the DC motor 210 from the high degree of rotational acceleration to the desired low degree of rotational acceleration, and therefore it is determined at a step S706 that the seatbelt locking mechanism 202 is normal, followed by terminating the present processing.

[0134]

On the other hand, if it is determined that the duty factor does not fall within the range between the first predetermined value and the second predetermined value, the duty factor of the control signal is not included within a range of duty factor within which the duty factor should fall in changing the rotational acceleration of the DC motor 210 from the high degree of rotational acceleration to the desired low degree of rotational acceleration, and therefore it is determined at a step S707 that the seatbelt locking mechanism 202 is abnormal.

[0135]

And then a warning is given to the occupant by means of the display device or the warning light (not shown) to warn him of the abnormality of the seatbelt locking mechanism 202 at a step S708, followed by terminating the present processing.

[0136]

If it is determined at the step S703 that the detected current i exceeds the predetermined value, that is, the DC motor 210 continues to be energized for rotation with the reel shaft 203 in the locked state, the duty factor of the control signal is further decreased at a step S709.

[0137]

Then, it is determined at a step S710 whether the duty factor of the control signal is the minimum, i.e. 0 %, and if it is the minimum, the processing proceeds to the step S705, whereas if it is not the minimum, the processing returns to the step S702.

[0138]

Fig. 12 is showing a view of the relationship between the duty factor of the control signal and time elapsed after the start of delivery of the control signal.

[0139]

In the figure, a point C represents a duty factor detected at the step S704 after it is determined at the step S703 that the detected current i is below the predetermined value (5 amperes).

The duty factor at the point C is 35 % which falls within the range between the first and second predetermined values (60 - 70 %) (the answer is YES at the step S705). Therefore, in this case, the duty factor of the control signal is included within a range of duty factor within which the duty factor should fall in changing the rotational acceleration of the DC motor 210 from the high degree of rotational acceleration to the desired low degree of rotational acceleration, and therefore it is determined at a step S706 that the seatbelt locking mechanism 202 is normal.

[0140]

On the other hand, a point D represents a duty factor detected at the step S704 after it is determined at the step S703 that the detected current i exceeds the predetermined value (5 amperes), then the duty factor is decreased (step S709), again the current i is detected (the answer is NO at the step S710, and at the step S702) and it is determined at the step S704 that the detected current i is below the predetermined value (5 amperes). The duty factor at the point D is 20 % which falls out of the range between the first and second predetermined values (the duty factor is below 30% or exceeds 40 %). Therefore, in this case, the duty factor of the control signal is not included within a range of duty factor within which the duty factor should fall in changing the rotational acceleration of the DC motor 210 from the high degree of rotational acceleration to the desired low degree of rotational acceleration, and therefore it is determined that the seatbelt locking mechanism 202 is abnormal (step S707).

[0141]

In the present control processing (fault diagnosis), only when it is determined at both of the steps S506 and S706 in Figs. 9 and 11 that the seatbelt locking mechanism 202 is functioning normally, it is finally determined that the same mechanism is normal, while when it is determined at either the step S507 in Fig. 9 or the step S707 in Fig. 11 that the seatbelt

locking mechanism 202 is functioning abnormally, it is immediately finally determined that the same mechanism is abnormal.

[0142]

As describe above, according to the third embodiment, if the DC motor 210 continues to be energized for rotation with the reel shaft 203 in the locked state, the duty factor of the control signal delivered from the MPU 214 to the DC motor driver 211 is detected at the step S504, and depending upon whether the duty factor of the control signal is included within a range of duty factor within which the duty factor should fall in changing the rotational acceleration of the DC motor 210 from the low degree of rotational acceleration to the desired high degree of rotational acceleration, it is determined at the steps S506 and S507 whether the seatbelt locking mechanism 2 is normal or abnormal. On the other hand, if the DC motor 210 continues to be energized for rotation with the reel shaft 203 in the unlocked state, the duty factor of the control signal delivered from the MPU 214 to the DC motor driver 211 is detected at the step S704, and depending upon whether the duty factor of the control signal is included within a range of duty factor within which the duty factor should fall in changing the rotational acceleration of the DC motor 210 from the high degree of rotational acceleration to the desired low degree of rotational acceleration, it is determined at the steps S706 and S707 whether the seatbelt locking mechanism 202 is normal or abnormal. Since the fault diagnosis is made based upon results of the above two kinds of determinations, accurate fault diagnosis of the seatbelt locking mechanism can be achieved.

[0143]

Further, since the results of the determinations (steps S506, S507, S706, and S707) are notified via the display device or warning light (steps S508 and 708). As a result, the occupant can understand the cause of the fault.

[0144]

Although in the present embodiment fault diagnosis is made based upon results of the two kinds of determinations, a plurality of kinds of control signals commanding to cause changes in the rotational acceleration in the seatbelt protracting direction from different degrees of low rotational acceleration to different degrees of high rotational acceleration, for example, and/or a plurality of kinds of control signals commanding to cause changes in the rotational acceleration in the seatbelt protracting direction from different degrees of high rotational acceleration to different degrees of low rotational acceleration, for example, may be delivered to the DC motor driver to carry out fault diagnosis based upon more than two kinds of determinations.

[0145]

Although in the above described second and third embodiments fault diagnosis of the seatbelt locking mechanism 202 is carried out based upon the current i flowing to the DC motor 210 and the duty factors of control signals delivered to the DC motor driver 211, alternatively fault diagnosis of the seatbelt locking mechanism 202 may be carried out based upon output signals from sensors which sense whether the reel shaft 203 is rotating, whether the reel shaft pulley 205 is rotating, whether the DC motor pulley 206 is rotating, and/or whether the power transmission belt 207 is operating.

[0146]

Further, fault diagnosis of the seatbelt locking mechanism 202 may be carried out by detecting acceleration applied to the vehicle during deceleration from the terminal voltage across the DC motor 210 or other parameters, and determining whether the seatbelt locking mechanism 202 operates in response to the detected acceleration. More specifically, when the acceleration applied to the vehicle exceeds a predetermined magnitude, if the seatbelt locking mechanism 202 operates, it is determined that the seatbelt locking mechanism 202 is normal, while if the seatbelt locking mechanism 202 does

not operate, it is determined that the seatbelt locking mechanism 202 is abnormal. On the other hand, when the acceleration applied to the vehicle is below a predetermined magnitude, if the seatbelt locking mechanism 202 operates, it is determined that the mechanism 202 is abnormal, while if the seatbelt locking mechanism 202 does not operate, it is determined that the mechanism is normal.

[0147]

Even by thus carrying out fault diagnosis of the seatbelt locking mechanism, based upon acceleration applied to the vehicle, accurate fault diagnosis of the seatbelt locking mechanism can be achieved.

[0148]

Furthermore, the acceleration applied to the vehicle may be detected by an acceleration sensor provided in the vehicle.

[0149]

Although in the second and third embodiments results of the determinations as to abnormality of the seatbelt locking mechanism 202 are notified by means of a display device or a warning light, alternatively any other type of warning device may be provided to give a warning when abnormality of the seatbelt locking mechanism 202 is detected as a result of the fault diagnosis.

[0150]

[Effect of the Invention]

As described in detail hereinabove, according to an automotive passenger restraint and protection apparatus as claimed in claim 1, the speed of protraction of the seatbelt is detected through an electric retractor, and at least one of actuation time of the airbag, expansion pressure of the airbag, actuation time of the pretensioner, a force of the pretensioner for retracting the seatbelt, and a force of the electric retractor for retracting the seatbelt is controled, based upon the speed of protraction of the seatbelt detected. As a result, the occupant can be properly protected in the event of a

collision of the automotive vehicle.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a view showing the arrangement of an electric retractor 100 provided in an automotive passenger restraint and protection apparatus according to a first embodiment of the present invention;

[Fig. 2]

Fig. 2 is a circuit diagram showing the construction of a DC motor driver 11;

[Fig. 3]

Fig. 3 is a view showing the construction of a pretensioner 19;

[Fig. 4]

Fig. 4 is a flowchart showing details of airbag and seatbelt driving control executed by an MPU 14 according to the present embodiment upon a collision of the automotive vehicle;

[Fig. 5]

Fig. 5 is a view showing the arrangement of an electric retractor 200 provided in an automotive passenger restraint and protection apparatus according to a second embodiment of the invention;

[Fig. 6]

Fig. 6 is a circuit diagram showing the construction of a DC motor driver 211;

[Fig. 7]

Fig. 7 is a flowchart showing an example of a fault diagnostic program executed by an MPU 214;

[Fig. 8]

Fig. 8 is a flowchart showing an example of the fault diagnostic program executed by the MPU 214;

[Fig. 9]

Fig. 9 is a flowchart showing an example of the fault diagnostic program executed by the MPU 214;

[Fig. 10]

Fig. 10 is showing a view of the relationship between a duty factor of a control signal and time elapsed after the start of delivery of the control signal;

[Fig. 11]

Fig. 11 is a flowchart showing an example of the fault diagnostic program executed by the MPU 214; and

[Fig. 12]

Fig. 12 is showing a view of the relationship between the duty factor of the control signal and time elapsed after the start of delivery of the control signal.

[Description of Reference Numerals]

1, 201 Frame

2, 202 Seatbelt Locking Mechanism

3, 203 Reel Shaft

5, 205 Reel Shaft Pulley

6, 206 DC Motor Pulley

7, 207 Power Transmission Belt

10, 210 DC Motor (Driving Means)

11, 211 DC Motor Driver (Driving Means)

14, 214 MPU (Control Means, Driving Signal Supplying Means, Abnormality Diagnosis Means)

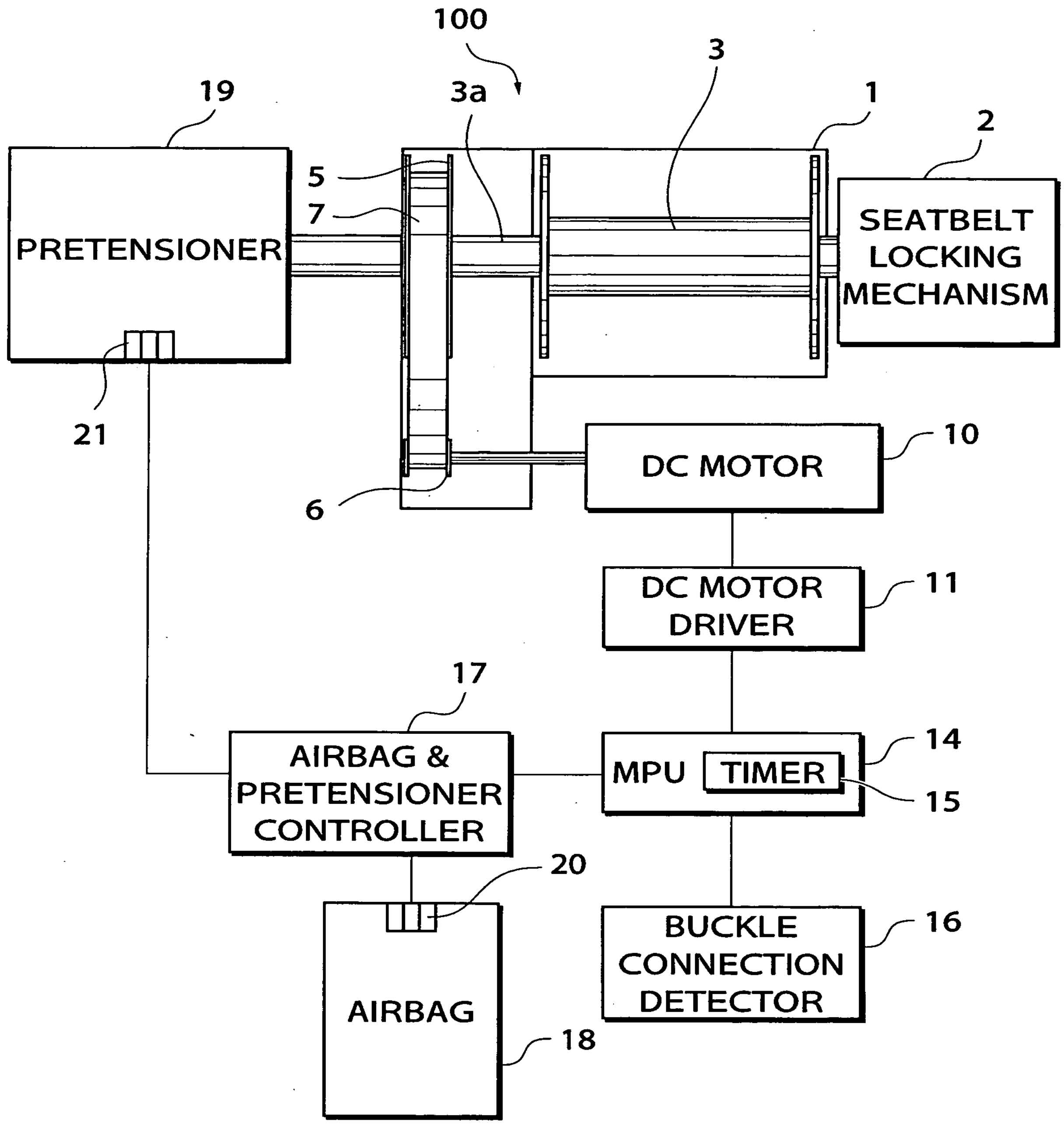
17 Airbag and Pretensioner Controller (Control Means)

18 Airbag

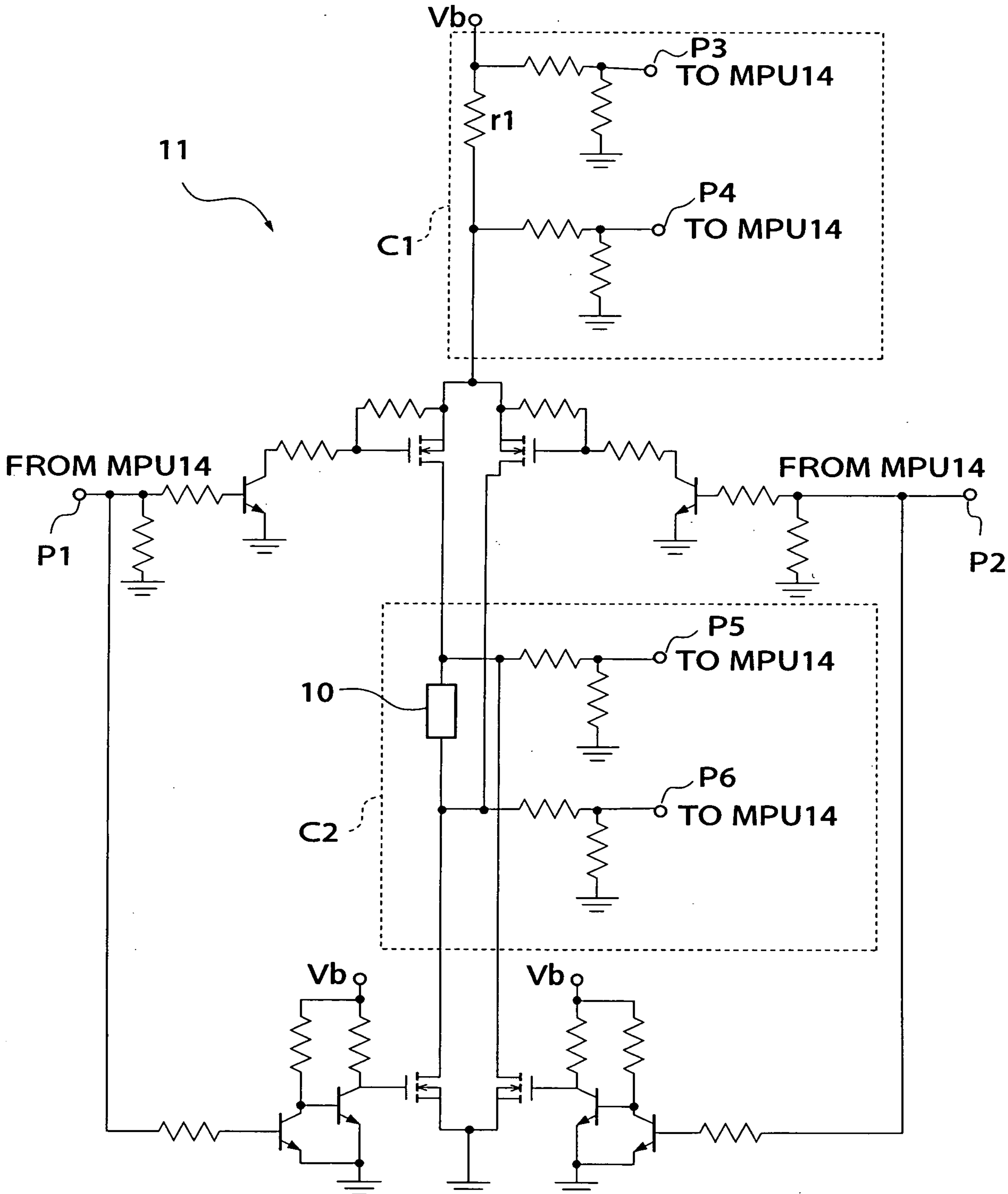
19 Pretensioner

100 Seatbelt Retractor

[Name of Document] DRAWINGS
[Fig. 1]

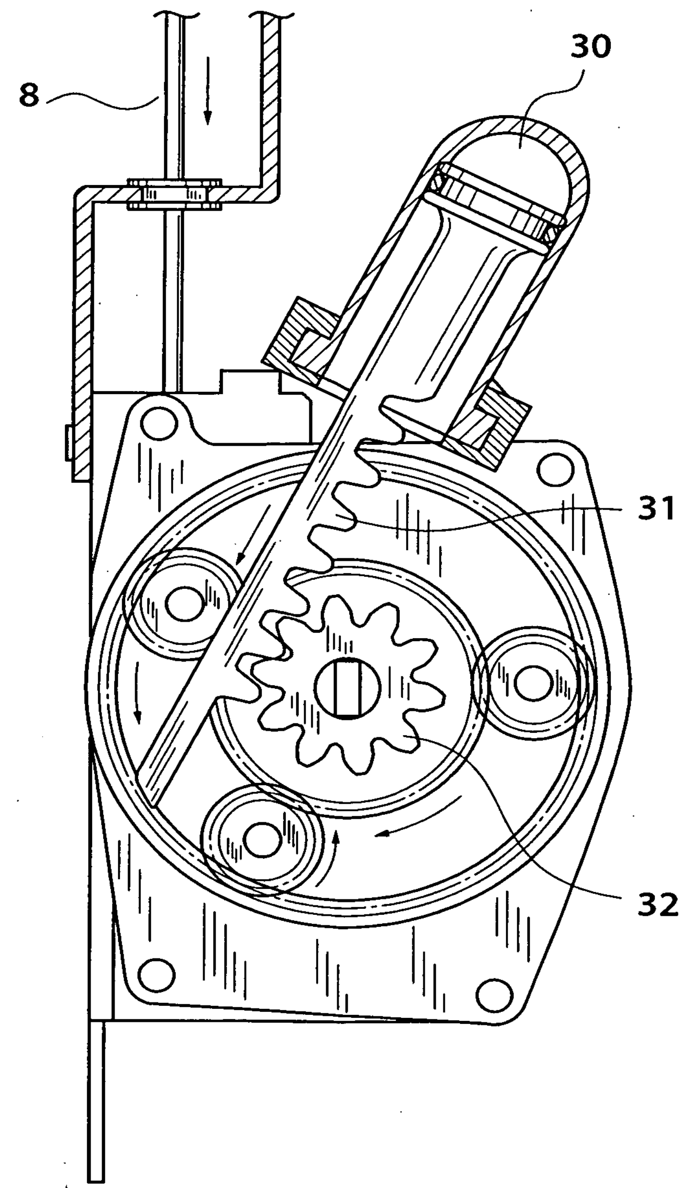


[Fig. 2]

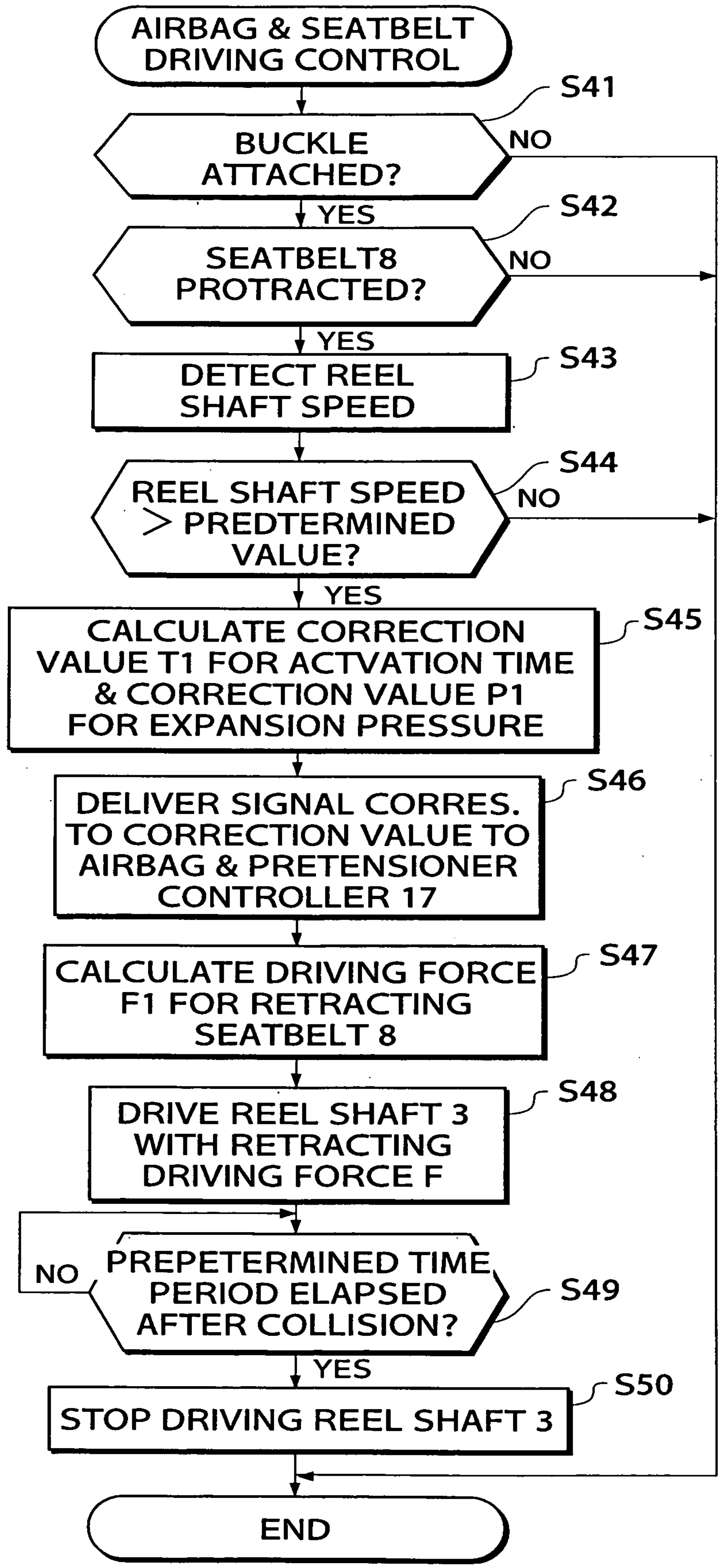


Vb
P3
TO MPU14
r1
11
P4
TO MPU14
C1
FROM MPU14
FROM MPU14
P1
P2
P5
TO MPU14
10
P6
TO MPU14
C2
Vb
Vb

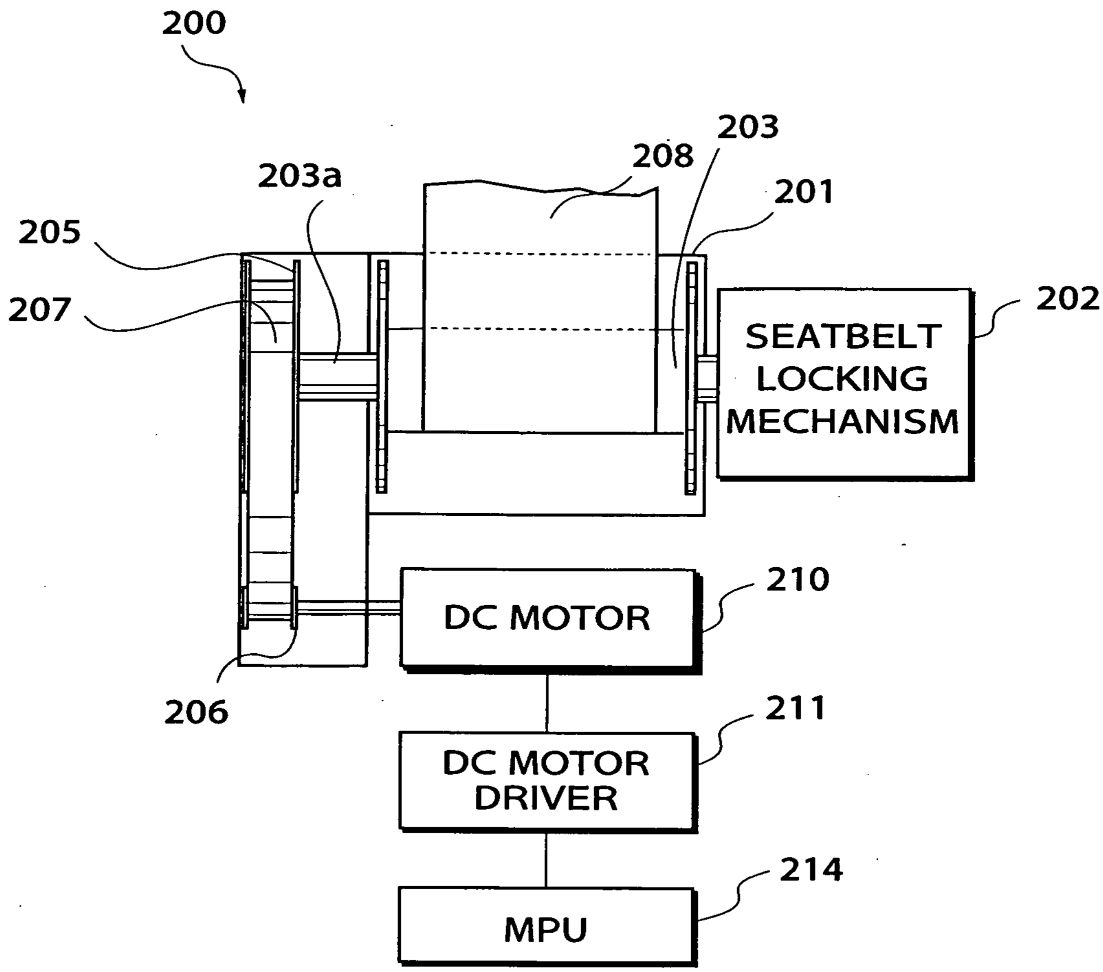
[Fig. 3]



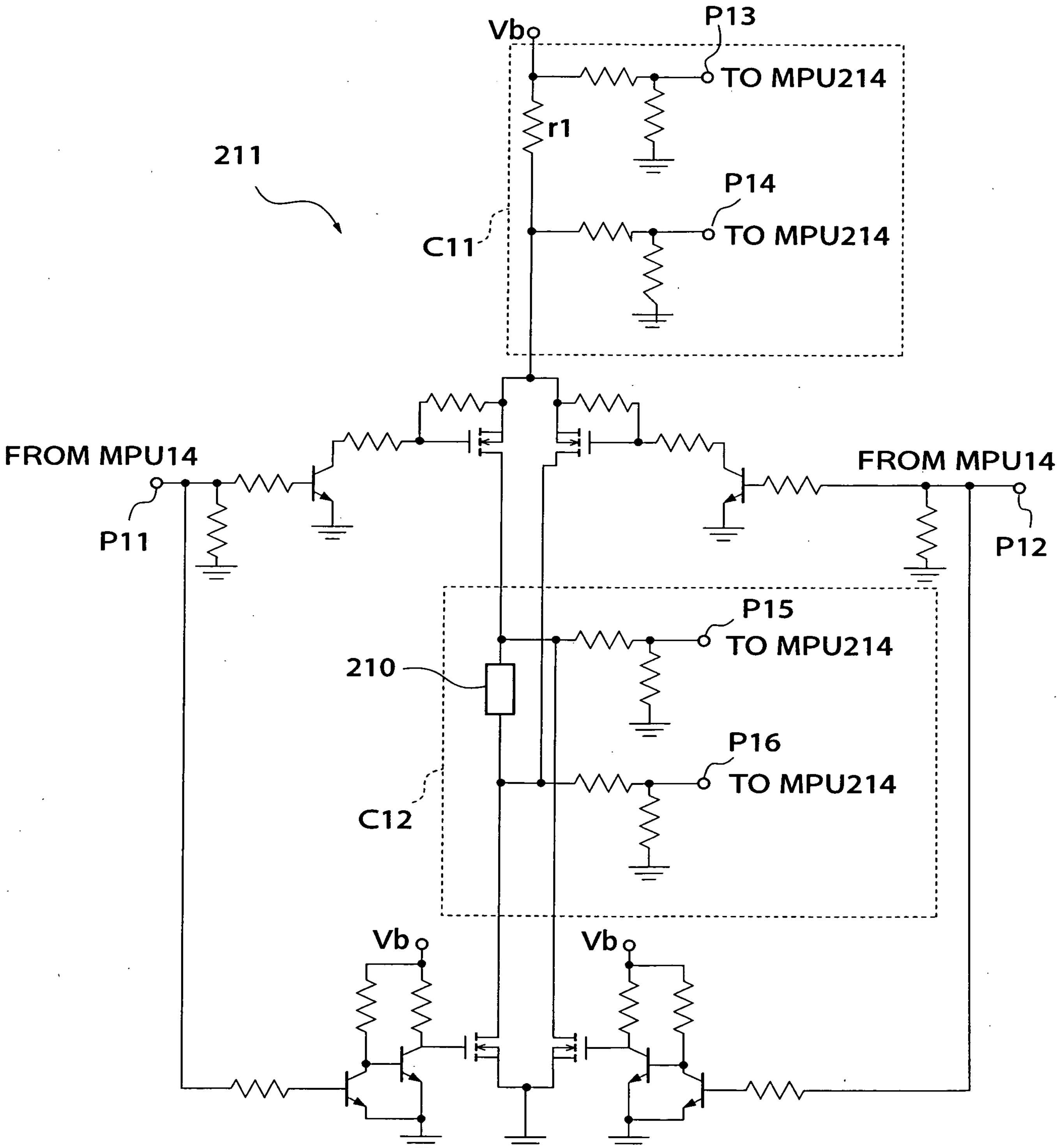
[Fig. 4]


AIRBAG & SEATBELT DRIVING CONTROL
S41
BUCKLE ATTACHED?
NO
YES
S42
SEATBELT8 PROTRACTED?
NO
YES
S43
DETECT REEL SHAFT SPEED
S44
REEL SHAFT SPEED > PREDTERMINED VALUE?
NO
YES
S45
CALCULATE CORRECTION VALUE T1 FOR ACTVATION TIME & CORRECTION VALUE P1 FOR EXPANSION PRESSURE
S46
DELIVER SIGNAL CORRES. TO CORRECTION VALUE TO AIRBAG & PRETENSIONER CONTROLLER 17
S47
CALCULATE DRIVING FORCE F1 FOR RETRACTING SEATBELT 8
S48
DRIVE REEL SHAFT 3 WITH RETRACTING DRIVING FORCE F
NO
PREPETERMINED TIME PERIOD ELAPSED AFTER COLLISION?
S49
YES
S50
STOP DRIVING REEL SHAFT 3
END

[Fig. 5]

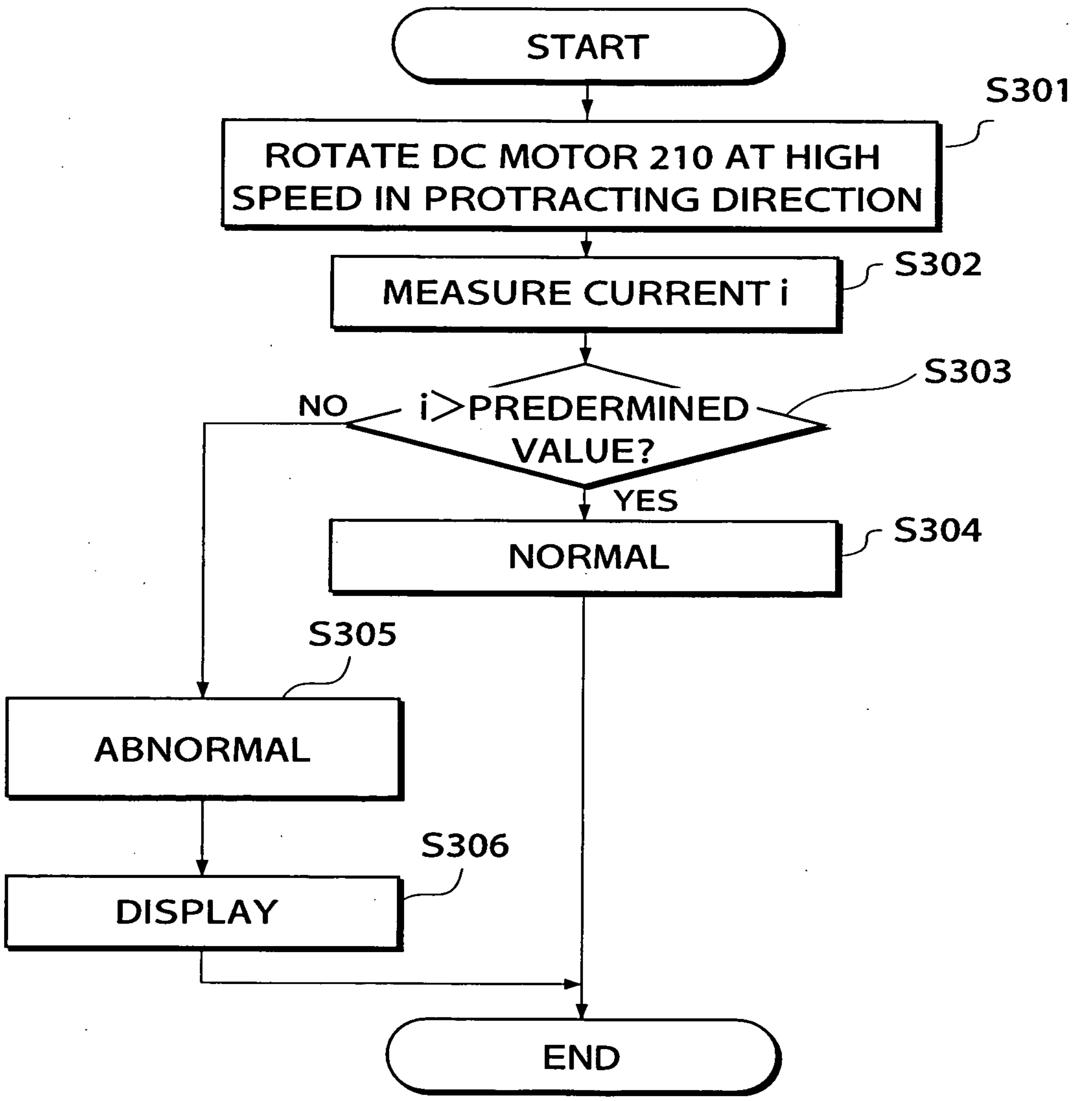

200
203
208
203a
201
205
202
207
SEATBELT LOCKING MECHANISM
210
DC MOTOR
206
211
DC MOTOR DRIVER
214
MPU

{Fig. 6]

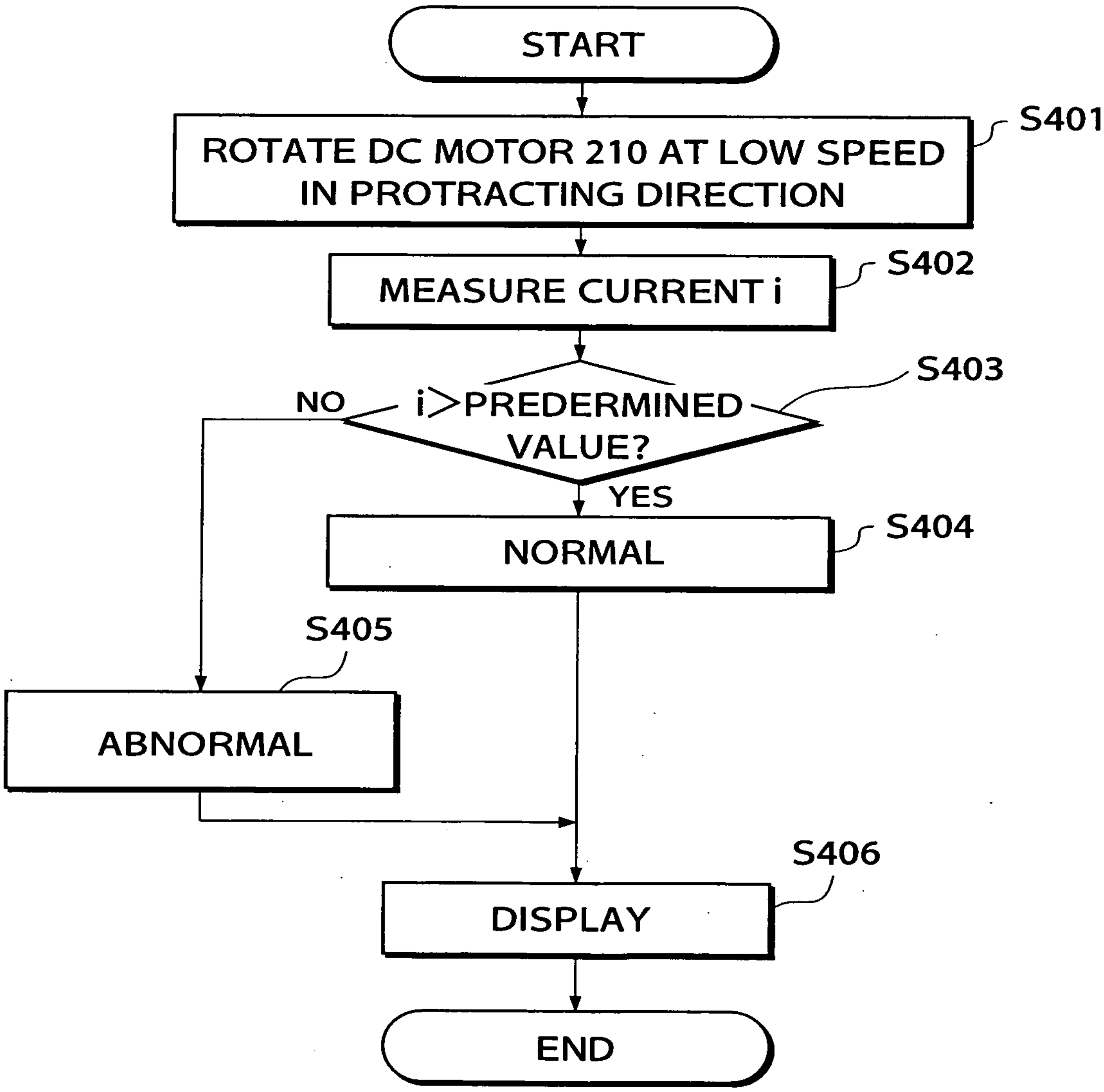


P13
Vb
TO MPU214
r1
211
P14
TO MPU214
C11
FROM MPU14
FROM MPU14
P11
P12
P15
TO MPU214
210
P16
TO MPU214
C12
Vb
Vb

[Fig. 7]

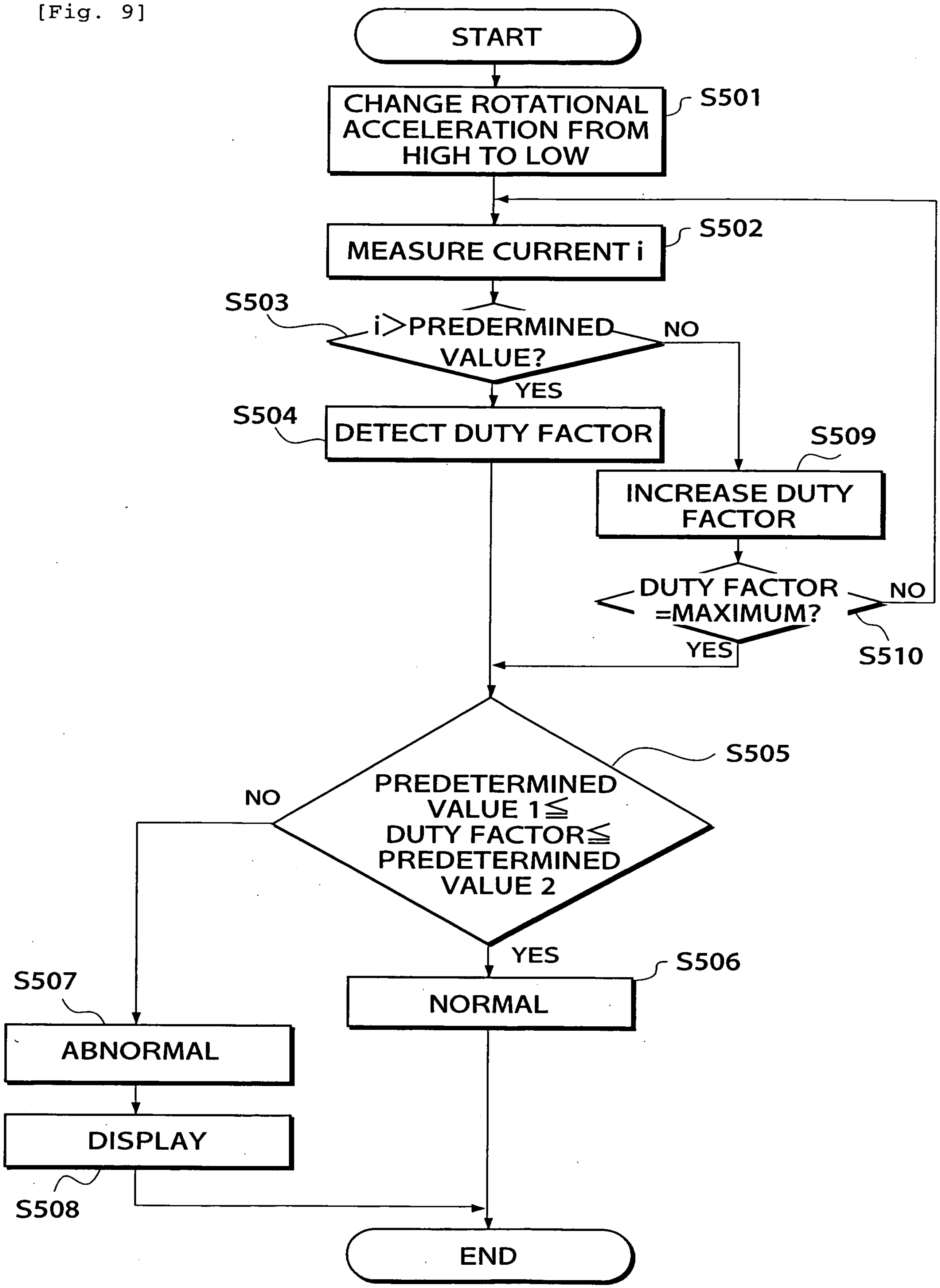

START
S301
ROTATE DC MOTOR 210 AT HIGH SPEED IN PROTRACTING DIRECTION
S302
MEASURE CURRENT i
S303
NO
i>PREDERMINED VALUE?
YES
S304
NORMAL
S305
ABNORMAL
S306
DISPLAY
END

[Fig. 8]



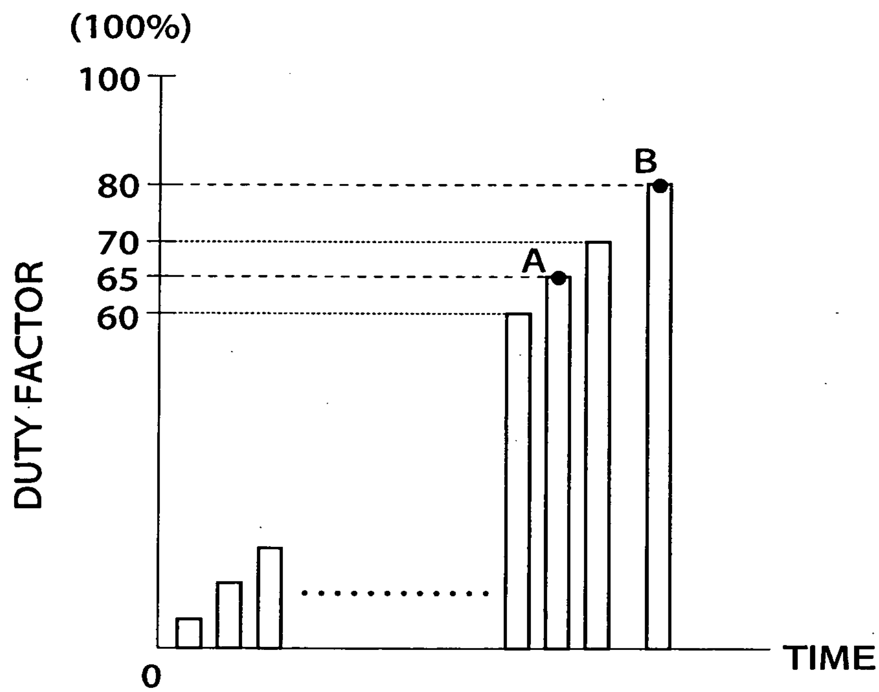
START
ROTATE DC MOTOR 210 AT LOW SPEED IN PROTRACTING DIRECTION
S401
MEASURE CURRENT i
S402
i>PREDERMINED VALUE?
S403
NO
YES
NORMAL
S404
S405
ABNORMAL
S406
DISPLAY
END

[Fig. 9]

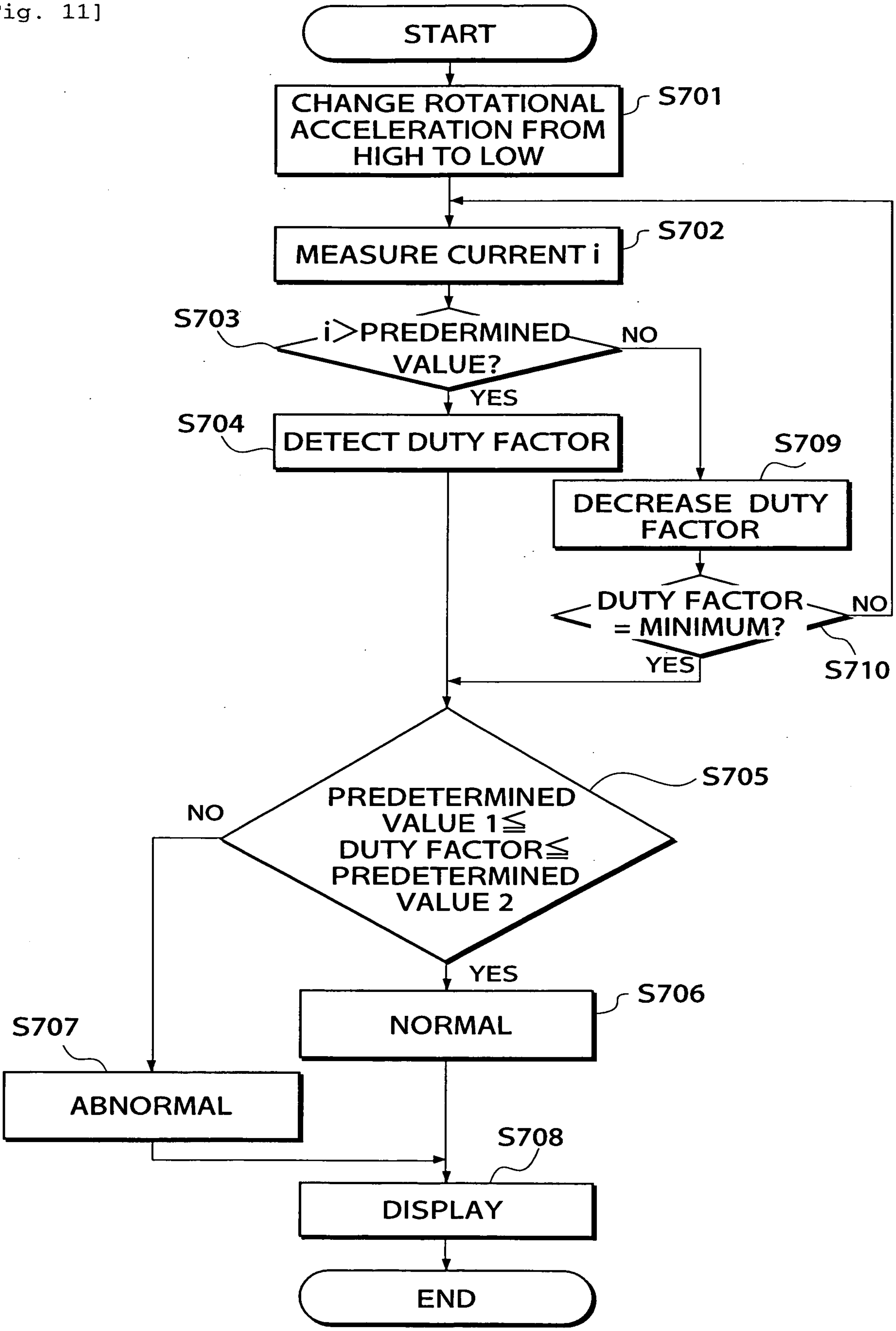


START
CHANGE ROTATIONAL ACCELERATION FROM HIGH TO LOW
S501
MEASURE CURRENT i
S502
S503
i>PREDERMINED VALUE?
NO
YES
S504
DETECT DUTY FACTOR
S509
INCREASE DUTY FACTOR
DUTY FACTOR =MAXIMUM?
NO
YES
S510
S505
PREDETERMINED VALUE 1≦ DUTY FACTOR≦ PREDETERMINED VALUE 2
NO
YES
S506
NORMAL
S507
ABNORMAL
DISPLAY
S508
END

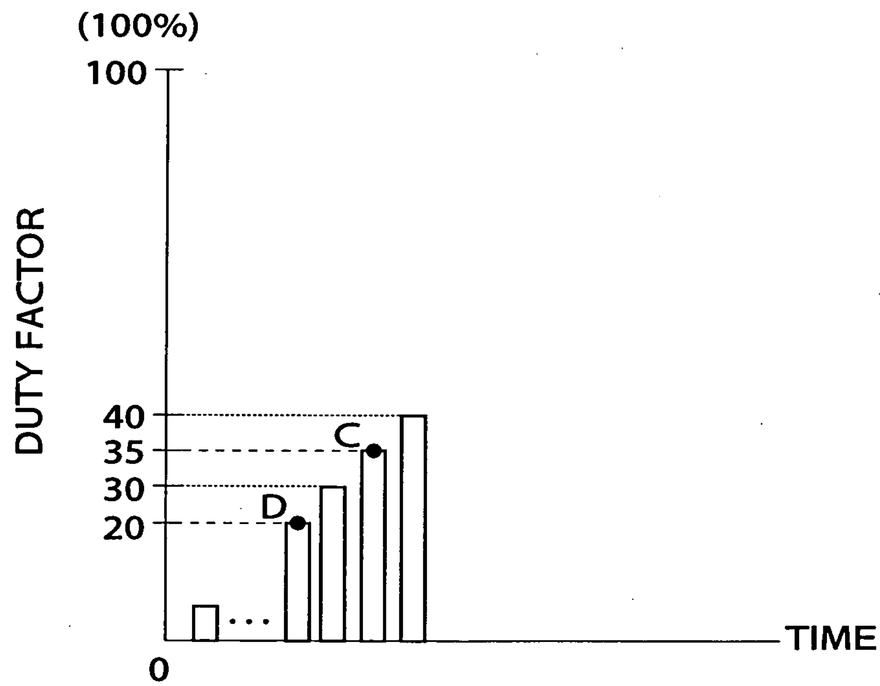
[Fig. 10]



[Fig. 11]


START
CHANGE ROTATIONAL ACCELERATION FROM HIGH TO LOW
S701
MEASURE CURRENT i
S702
S703
i>PREDETERMINED VALUE?
NO
YES
S704
DETECT DUTY FACTOR
S709
DECREASE DUTY FACTOR
DUTY FACTOR = MINIMUM?
NO
YES
S710
PREDETERMINED VALUE 1≦ DUTY FACTOR≦ PREDETERMINED VALUE 2
S705
NO
YES
S706
NORMAL
S707
ABNORMAL
S708
DISPLAY
END

[Fig. 12]



[Name of Document] WRITTEN ABSTRACT

[Abstract]

[Object] To provide an automotive passenger restraint and protection apparatus which is capable of properly protecting the occupant in the event of a collision of an automotive vehicle.

[Construction] A value T of the actuation times of an airbag 18 and a pretensioner 19, and a value P of the expansion pressure of the airbag 18 and the seatbelt retracting force of the pretensioner 19 are variably set according to terminal voltage across a DC motor 10 with its terminals open and a rotational speed v of a reel shaft 3 (steps S45 and S46, and formulas (1) to (4)). Then, the driving force F of the reel shaft 3 for retracting the seatbelt 8 can be variably set according to the terminal voltage across the DC motor 10 with its terminals open or the rotational speed v of the reel shaft 3 (steps S47 and S48, and formulas (5) and (6)).

[Selected Figure] Fig. 4